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Two new Australian species and a new combination in *Muehlenbeckia* (Polygonaceae)

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Abstract

Two new species of *Muehlenbeckia* Meisn. are described, and a key is provided to these and similar species in eastern Australia. *Muehlenbeckia arnhemica* K.L.Wilson & Makinson grows on rocky outcrops in the northern tropical part of the Northern Territory. *Muehlenbeckia costata* K.L.Wilson & Makinson is restricted to rocky outcrops in ranges in southeastern Queensland and northern New South Wales. A new combination is made for *M. stenophylla* F.Muell. as a subspecies of *M. diclina* (F.Muell.) F.Muell., and lectotypes are selected for these two names.

Keywords: Polygonaceae; Systematics; Australia; Fire-ephemeral

Introduction

Two new species of *Muehlenbeckia* Meisn. are here described. They were distinguished while revising the genus and preparing treatments of the family Polygonaceae for the *Flora of New South Wales* (Wilson 1990) and the *Flora of Australia* (Wilson and Makinson, submitted). They are both pioneering fire-ephemerals, germinating from the soil seedbank or regenerating from rootstocks after bushfires and growing prolifically for several years before senescence or regrowth of other species crowds them out (Russell-Smith 1986; Hunter 1995). Hunter *et al*. (1998) suggested that the decline in populations of *M. costata* K.L.Wilson & Makinson is exacerbated by the presence of a rust fungus on vegetative parts.

Recognition of these new species is based on morphological features. Their status is supported in a molecular study by Schuster *et al*. (2011) of *Muehlenbeckia, Duma* T.M.Schust., *Fallopia* Adans. and *Reynoutria* Houtt. That study used five chloroplast regions (*mat*K, *ndh*F, 3´*rps*16-5´*trn*K, *trn*L-*trn*F and 3´*trn*V-*ndh*C) and two nuclear gene regions (second intron of LEAFY and ITS) to assess the monophyly and phylogeny of these groups. *M. arnhemica* K.L.Wilson & Makinson was sister to *M. zippelii* (Meisn.) Danser (another tropical climbing species, found in Queensland (Cape York) and New Guinea), while *M. costata* was sister to *M. gracillima* Meisn. and *M. adpressa* (Labill.) Meisn., both occurring in temperate Australia.

Muehlenbeckia stenophylla F.Muell. has been considered a synonym of *M. diclina* (F.Muell.) F.Muell. but morphological and ecological differences and geographic separation led us to the conclusion that the former should be recognised as a subspecies of the latter. The relevant combination is made here and lectotypes are selected.

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Material and methods

Morphological features were examined in the field and in herbaria to assess the status of the taxa recognised here. Specimens were consulted in the following herbaria: AD, B, BRI, CANB, CNS, DNA, E, FI, G, K, MEL, NE, NSW, PERTH. Cited specimens have been seen except for those indicated as 'n.v.'

Maps were produced using SimpleMappr (Shorthouse 2010), with specimen records from the Australasian Virtual Herbarium (https://avh.ala.org.au/ (accessed June 2023) and our own records of specimens seen by us.

There is still no generally agreed system for describing inflorescences (see, for example, Endress 2010, Classen-Bockhoff and Bull-Hereñu 2013). Inflorescences in *Muehlenbeckia* ('flowering shoot systems' in the terminology of Classen-Bockhoff and Bell-Hereñu 2013) are complex structures, as discussed by Brandbyge (1992), with the basic inflorescence unit (i.e., the structures enclosed by an ocrea that may appear superficially to be a single flower or a cluster of flowers) described by him as a 'condensed cymose entity'. Descriptive terms commonly used, especially in Flora treatments (e.g. Wilson 1990, Walsh 1996, Short 2011), include terminal or axillary, spike or spike-like, raceme or raceme-like, panicle or panicle-like, and [flowers] solitary. We have not investigated the ontogeny of these structures, so we are using commonly used terms to describe the superficial appearance of the inflorescences. Flowers are shortly pedicellate so we use the term 'raceme' for the raceme-like partial inflorescences.

Taxonomy

Muehlenbeckia arnhemica K.L.Wilson & Makinson, sp. nov.

Type: Northern Territory: Nawurlandja (formerly Little Nourlangie Rock), Kakadu National Park, *K.L. Wilson 9672, J.J. Bruhl, K.L. Clarke & I.D. Cowie,* 14 March 1999 (♀, ♂ – monoecious; holo (mounted on 2 sheets): NSW 785289, NSW 1102070; iso: BRI, CANB, DNA, K, MO, NE). Figure 1.

Diagnosis: *M. arnhemica* is a scrambler, twiner, or decumbent subshrub. It is allied to *M. zippelii*, differing from that species in the following features: leaves with a shortly acuminate to obtuse apex (versus leaves with an elongated 'drip-tip' 5–20 mm long in *M. zippelii*), inflorescence with partial inflorescences elongated and raceme-like but less conspicuous and less branched than in *M. zippelii*, and nut broad-elliptic in outline (versus elliptical in *M. zippelii*). *M. zippelii* is a much stronger climber than *M. arnhemica*.

Muehlenbeckia sp. Mt Brockman (L.A.Craven 2357) K.L.Wilson & Makinson, *sensu* Australian Plant Name Index (https://biodiversity.org.au/nsl/services/rest/name/apni/222208/api/apni-format, accessed 23 August 2023).

Illustrations: Brandbyge (1992: fig. 6B), fruit, as *M. rhyticarya*; Short (2011: fig. 2), as *M.* sp. Mt Brockman (L.A. Craven 2357).

Scrambler, twiner, or decumbent subshrub, forming thickets to 2 m high; dioecious or rarely monoecious. Stems becoming woody with age, to c. 5 mm diam., green to reddish, not glaucous, smooth or weakly and regularly striate. Leaves simple, solitary, persistent, semi-succulent, glabrous, bright green, slightly discolorous, not or rarely slightly glaucous, petiolate; petiole 10–35 mm long, usually about 1/2 as long as blade or slightly shorter, with small extra-floral pit nectary present abaxially at base; blade cordate to ovate, 20–80 mm long, 10–55 mm wide; distal third of blade with edges more or less convex; base truncate to cordate; margins smooth or finely crisped, flat; apex shortly acuminate to obtuse; ocrea short-tubular, not ciliate on upper margin, soon disintegrating. Inflorescence compound, with lax terminal or axillary raceme-like partial inflorescences 5–20 cm long, often crowded sub-terminally. Flowers shortly pedicellate, 2–5 per cluster. Perianth 5-merous, sepaloid, divided for most of its length; perianth segments 1.3–2.5 mm long, persistent, greenish white, in fruiting stage enlarged, whitish and fleshy, papery when dry. Stamens 8; anthers 0.5–0.9 mm long. Style 3-fid. Nut broad-elliptical in outline, subglobose to trigonous in cross-section, 2.7–3.5 mm long, 2.2–3.3 mm diam., black, ± shining, strongly transversely rugose and minutely granulate, partly enclosed by persistent perianth. Figure 2A.

Distribution and habitat: Endemic to the Top End of the Northern Territory (in Kakadu National Park and Arnhem Land), extending to Elcho and Melville Islands (Figure 3). In tall heath on sandstone and in monsoon forests, usually on sandy soils; common after disturbance such as fire.

Conservation status: Apparently widespread in its region of occurrence, including in Kakadu National Park, and in rocky sites likely to be subject to relatively infrequent or low-intensity fires, therefore assessed (Ian Cowie, pers. comm.) as of Least Concern (IUCN 2022).

Etymology: The specific epithet refers to the occurrence of this species mainly in the Arnhem Land region of the Top End of the Northern Territory. The region acquired its name from the Dutch East India Company ship *Arnhem*, which sailed into the Gulf of Carpentaria in 1623. The ship was named after the city of Arnhem in The Netherlands.

Common name: None known.

Notes: The species seems to be mainly dioecious but is at least occasionally monoecious (e.g., the type specimen).

The molecular analysis of Schuster *et al*. (2011) found *M. arnhemica* to be sister to *M. zippelii*, which is a robust climber (climbing to about 10 m up trees) found in north-eastern Queensland and New Guinea. *Muehlenbeckia arnhemica* differs from that species in having leaves with a shortly acuminate to obtuse apex (versus leaves with a 'drip-tip' 5–20 mm long in *M. zippelii*), inflorescence 'racemes' more conspicuous and often much-branched in *M. zippelii*, and nut shape (broad-elliptic in outline in *M. arnhemica* versus elliptical in *M. zippelii*). The collection *Dunlop 3943* from Elcho Island has a somewhat more pointed apex to the fruit, approaching *M. zippelii* in this, but in other features it agrees closely with mainland populations of *M. arnhemica*.

In the past, this species has been referred to *M. rhyticarya* F.Muell. ex Benth. However, our study of morphological characters, distribution and regeneration strategies found that these are distinct taxa. *M. rhyticarya* occurs in temperate to subtropical eastern Australia, differing from *M. arnhemica* in usually being an erect subshrub (sometimes decumbent; not woody), with leaves that are usually glaucous (often less so when young) with an apex usually obtuse to emarginate (occasionally acute), with a fruiting perianth that is more succulent and whitish with a tinge of pink at maturity, and with a nut that is more acutely trigonous and ovate in outline. In addition, *M. rhyticarya* is a reseeder after fire, not a resprouter like *M. arnhemica* (Russell-Smith 1986).

Figure 1. *Muehlenbeckia arnhemica* holotype (two sheets: NSW 785289, NSW 1102070).

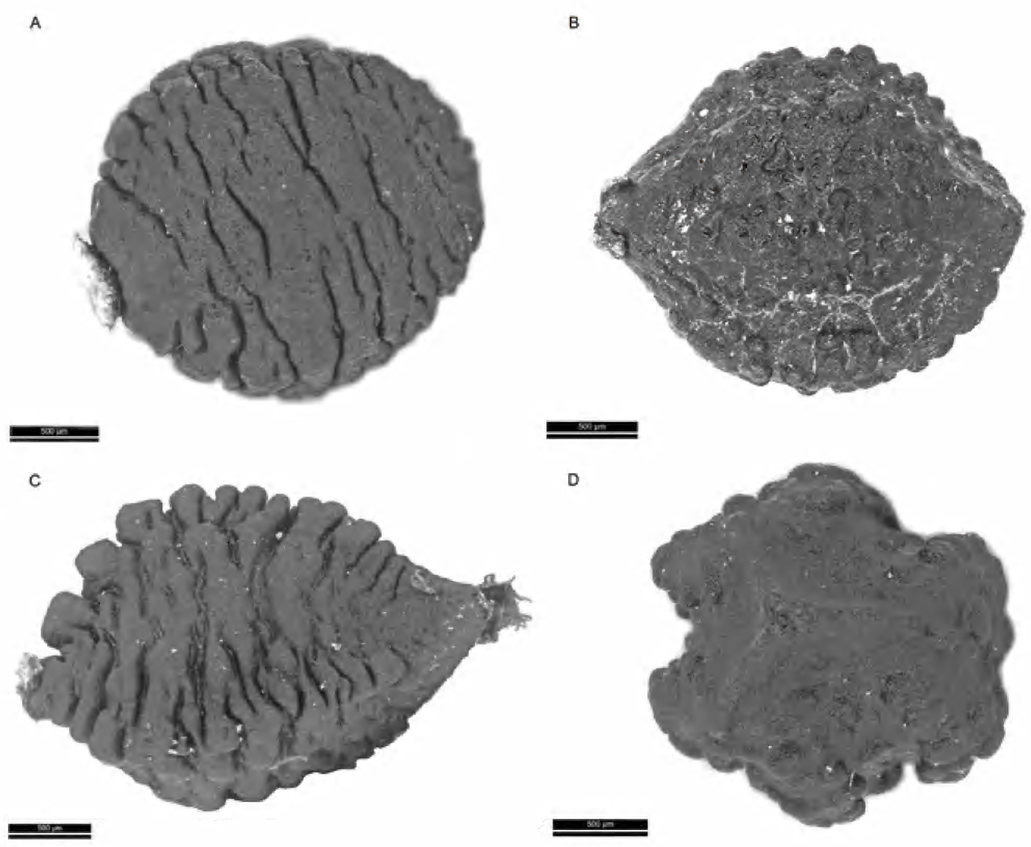

Figure 2. Fruits of A, *Muehlenbeckia arnhemica* (NSW 785289); B, *M. costata* (side view; NSW 1101932); C, *M. rhyticarya* (NSW 775891); D, *M. costata* (top view, with scar of style base in centre and showing the three longitudinal ridges near apex and six broader ribs and tubercles below; NSW 1101933). Scale bar = 500 µm.

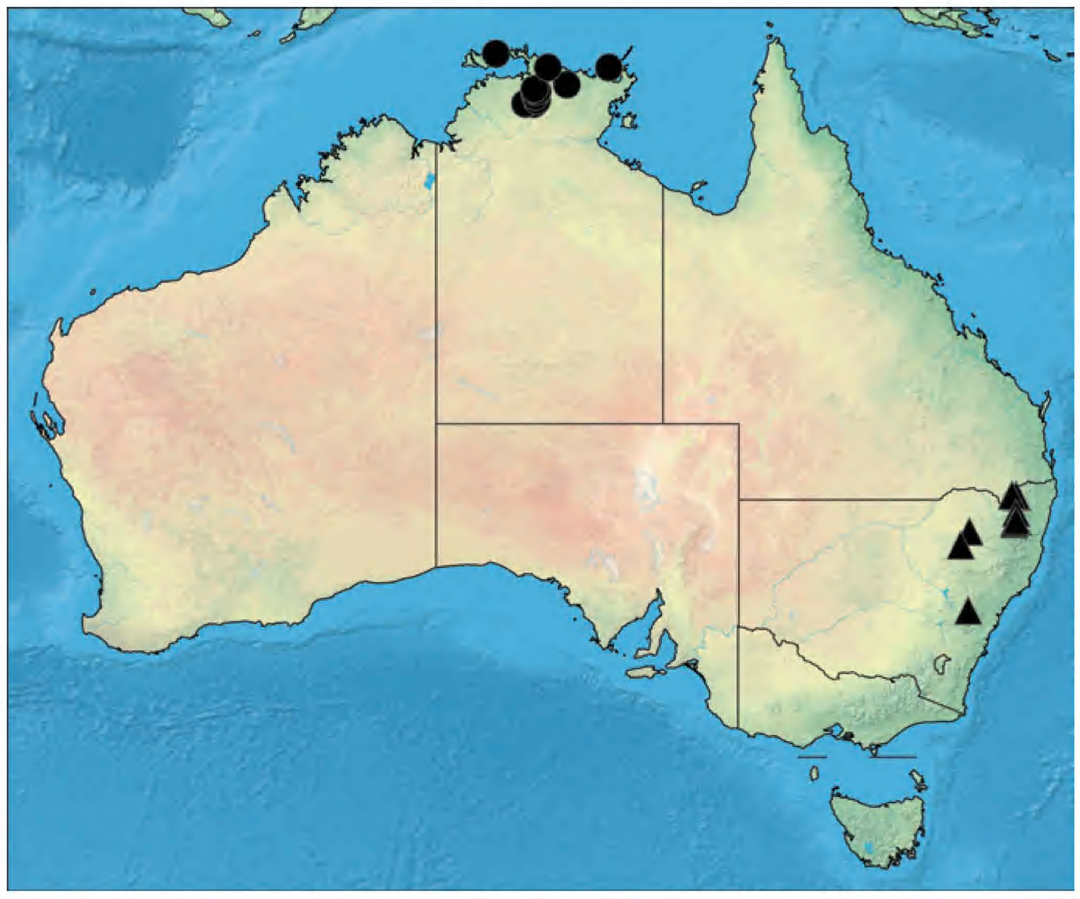

Figure 3. Distribution of *Muehlenbeckia arnhemica* (circles) and *M. costata* (triangles).

Selected specimens examined: Northern Territory: Arnhem Land, Mount Brockman Range c. 15 km S of Jabiru, *L.G. Adams & L.A. Craven 3063*, 23 Feb 1973 (♀, BRI-AQ277371, CANB 273638, DNA A0063585, G, K, NSW 1101905); c. 56 km S of Maningrida, Arnhem Land, *I.D. Cowie 8551*, 17 Mar 2000 (♀, DNA D0140753, NSW 522284); N facing wall in central part of Mount Brockman, *L.A. Craven 2357*, 23 Feb 1973 (♂, BRI 238137, CANB 271513, DNA A0055597, PERTH), *L.A. Craven & E. Eversons 2358*, 23 Feb 1973 (♀, BRI 238136, CANB, DNA A0055648); 17.5 km SSE of Koongarra, *L.A. Craven 6270*, 2 June 1980 (♂, BRI 285139, CANB, DNA D0144437, MEL 605667); Arnhem Land, Lightning Dreaming, *C. Dunlop 6584 & G. Wightman*, 22 Feb 1984 (♀, DNA D0023043); Elcho Island, *C. Dunlop 3943*, 18 July 1975 (♂, DNA D0009690), (♀, CANB 256984, DNA A0047991, K); Pullchoo Bay, Melville Island, *R. Fensham 907*, 27 June 1988 (♂, DNA D0045861); Mount Brockman Outlier, 15 km SE of Jabiru, *R.W. Johnson 4787*, 20 Apr 1989 (♀, BRI-AQ657088, CANB 539888, DNA D0152877, NSW 811743); Mount Brockman, Kakadu, *J. Russell-Smith 8040 & D. Lucas*, 20 Apr 1989 (♀, DNA D0041833, MEL 1583505, NSW 811744); 7 km WSW of King River mouth, *J. Russell-Smith 3719 & D. Lucas*, 23 Oct 1987 (vegetative; DNA D0031368); southern end of Mount Brockman outlier, Kakadu National Park, *K.L. Wilson 9707, J.J. Bruhl, K.L. Clarke & I.D. Cowie,* 16 Mar 1999 (♀, DNA, NE, NSW 785325).

Muehlenbeckia costata K.L.Wilson & Makinson, sp. nov.

Type: New South Wales: Kaputar West Rock Lookout, Mt Kaputar National Park, *K.L. Wilson 6990 & R.O. Makinson*, 29 Nov 1986 (♀; holo: NSW 894301; iso: BRI, K, NY). Figure 4.

Diagnosis: *Muehlenbeckia costata* is a decumbent to scrambling subshrub. It was previously lumped into *M. rhyticarya* F.Muell. ex Benth., but it differs from that species in its habit (*M. rhyticarya* is an erect subshrub – occasionally decumbent); its non-glaucous and yellow-green leaves (glaucous at least at maturity in *M. rhyticarya)*, with strongly crisped leaf margins (usually smooth and even in *M. rhyticarya*); and its subterete to broadly trigonous nut with secondary, longitudinal ridges (trigonous and lacking secondary ridges in *M. rhyticarya*).

Muehlenbeckia sp. Mt Norman (J.T. Hunter 3847) *sensu* Australian Plant Name Index (https://biodiversity.org.au/nsl/services/rest/name/apni/222209/api/apni-format, accessed 23 August 2023).

Muehlenbeckia sp. (Stanthorpe A.R. Bean 12466) *sensu* Queensland Herbarium, *p.p.* (https://www.data.qld.gov.au/dataset/census-of-the-queensland-flora-and-fungi-2022 accessed 7 July 2023).

Illustrations: Wilson (1990: 286); Hunter *et al.* (1998: figs 1, 2); NSW Office of Environment and Heritage (2023).

Scrambling or climbing subshrub or twiner to 4 m in height, dioecious. Stems slender, green to reddish, not glaucous, weakly striate, to 5 m long. Leaves solitary, simple, persistent, not succulent, yellow-green, slightly paler abaxially, often reddish on margins and veins, not glaucous, petiolate; petiole 10–20(–25) mm long, usually no more than 1/3 as long as blade, with small extra-floral pit nectary present abaxially at base; blade ovate to oblong-ovate, 25–75(–140) mm long, 10–50(–90) mm wide; distal third of blade with edges strongly convex; base truncate to more or less cordate or sagittate; margins strongly crisped, slightly wavy; apex obtuse, emarginate, or acute, occasionally short-apiculate (apiculum to 3 mm long); ocrea short-tubular, not ciliate on upper margin, soon disintegrating. Inflorescence compound, consisting of several to numerous axillary ‘racemes’ 0.5–10 cm long. Flowers shortly pedicellate, 2–5 per cluster. Perianth 5-merous, sepaloid, divided for 2/3–3/4 of its length in female flowers, rather more in male flowers; perianth segments 1.5–2.0 mm long, persistent, greenish becoming orange and fleshy in fruiting stage, papery when dry. Stamens 8; anthers 0.7–0.9 mm long. Style 3-fid. Nut broad-elliptical in outline, subterete to broadly trigonous, 3–4 mm long, with (3–)6 broad rounded longitudinal ridges, black, dull, usually prominently tuberculate, partly enclosed by persistent perianth. Figure 2B.

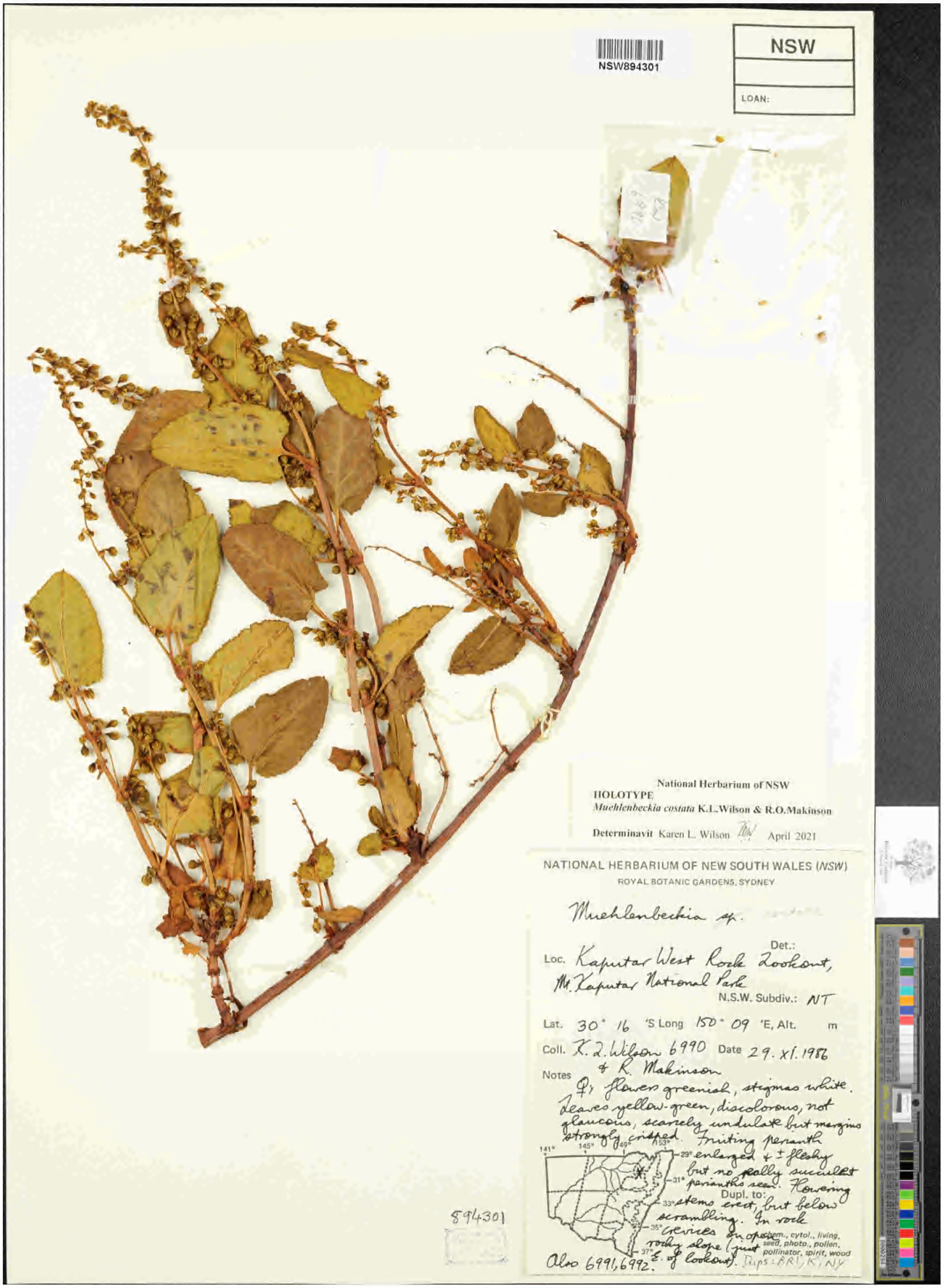

Figure 4. *Muehlenbeckia costata* holotype (NSW 893401).

Distribution and habitat: At higher altitudes (c. 1100 m) on the New England Batholith, south from Mount Norman near Wallangarra, Queensland, and the adjoining Bald Rock area in New South Wales, to the mountains east of Guyra, extending to the Nandewar Range (Mt Lindesay, Mt Kaputar), and with an outlying occurrence on an isolated lower peak in the Willala Aboriginal Area on the eastern edge of the Pilliga Scrub (observed and photographed there by John Hunter (2011), not vouchered; NSW Office of Environment and Heritage (2013)). An old (1901) specimen from Wallerawang near Lithgow (NSW Central Tablelands), while morphologically congruent with other material, is very disjunct from the nearest known occurrences in the Nandewar Range and Pilliga, and at a much lower altitude (c. 480 m) compared to the main populations closer to the Queensland–New South Wales border. We have searched without success in the broad Wallerawang area, but it is possible that the plant was collected from a site that is now under water in Lake Wallace. Figure 3.

Associated with big granitic, adamellite, basaltic and other igneous outcrops on the New England Batholith and Nandewar Range, in heath and more open areas of dry sclerophyll forests. The isolated occurrence in the Pilliga Scrub is reported to be on sandstone and the other isolated collection from near Wallerawang is also likely to be on sandstone.

Conservation status: Listed as Vulnerable (Schedule 2) in New South Wales legislation (NSW Office of Environment and Heritage 2023); as Least Concern in Queensland (*Nature Conservation Act* (NCA) status). A listing as Endangered may be more appropriate, given its fragmented and spasmodic occurrence, but most known populations are protected in national parks.

Etymology: The specific epithet refers to the prominent longitudinal ribs on the fruit; from the Latin *costa*, a rib.

Common name: Scrambling Lignum (NSW Office of Environment and Heritage 2023).

Notes: A relatively widely distributed species but of restricted habitat. It behaves as a pioneer fire-ephemeral and an obligate seeder (Hunter 1995; Hunter and Clarke 1998; Hunter *et al*. 1998). It is abundant after fire, germinating from the seed bank and then persisting for up to three years (Hunter *et al*. 1998), but otherwise rarely emergent, surviving as diaspores in the soil seed bank. It produces abundant hard-coated seeds surrounded by the persistent enlarged, orange-coloured perianth. This probably indicates dispersal by birds and perhaps lizards (Hunter *et al*. 1998).

Male inflorescences tend to be laxer and more elongated (e.g., in *S.T. Blake 23714*) than female inflorescences.

This taxon was previously referred to *M. rhyticarya* F.Muell. ex Benth., which occurs in the same regions as *M. costata* although they are not sympatric. *M. rhyticarya* differs from *M. costata* in being an erect subshrub (occasionally decumbent) versus scrambling and climbing in *M. costata* and in having glaucous stems and leaves (less so when young) versus non-glaucous and yellow-green in *M. costata*, leaf margins usually smooth (strongly crisped in *M. costata*, and often reddish), and a nut that is trigonous, lacking prominent longitudinal ridges. Both species are most common after fire, but plants of *M. rhyticarya* often persist for more years than *M. costata*, which only persists for 2–3 years.

Selected specimens examined: Queensland: Darling Downs: Girraween National Park near Wallangarra, slopes of Mount Norman, *S.T. Blake 23714*, 4 Nov 1971 (♂, BRI 134103); S of Mount Norman, Girraween National Park, alt. 1230 m, *J.T. Hunter 3456*, 6 Aug 1995 (♀, BRI, NE 63992, NSW 470829); Border Trail between Girraween and Bald Rock National Parks, *J.T. Hunter 3847*, 16 Feb 1996 (♀, AD, B, CANB 697012, DNA D0135815, HO 329774, K, MEL 266330, NE 63690, NSW 500358, QRS 120413).

New South Wales: Northern Tablelands: Mount Lindesay, Nandewar Mtns, *R.H. Cambage 2391*, Nov 1909 (♂, NSW 1101934); Mount Kaputar, 38 km ENE of Narrabri, *R. Coveny 8870 & S.K. Roy*, 20 Nov 1979 (♀, NSW 1101934); Bald Rock, Bald Rock National Park, alt. 1165 m, *J.T. Hunter 3209*, 31 May 1995 (♀, NE 63214, NSW 396849); West Kaputar Rocks, Mount Kaputar National Park, *P. Merrotsy s.n.*, 8 Feb 1987 (♀, NSW 1101926); Kaputar Road, c. 1.4 km W of intersection with Summit Road, Mount Kaputar National Park, *G.P. Phillips 1110 & L.M. Copeland,* 23 Apr 2020 (♀, NSW 1098868); 200 m NW of Scott Trig. point, Compartment 211, Butterleaf State Forest, alt. 1320 m, *P.G. Richards 533, D. Moffatt & J. Hunter*, 18 Jun 1996 (vegetative, NE 72971, NSW 411135); Kaputar West Rock Lookout, Mount Kaputar National Park, *K.L. Wilson 6991, 6992 & R. Makinson*, 29 Nov 1986 (♀, NSW 1101933, 1101932); saddle between Crown Mountain and Nightcap Mountain, Warra State Forest, alt. 1330 m, *K.L. Wilson 9399, K.D. Hill, L.C. Stanberg & J. Hunter*, 23 Feb 1996 (♀, NSW 400541, 811742), *9401 et al.* (♂, NSW 40052). Central Tablelands: Wallerawang, *J.L. Boorman,* Oct 1901 (♀, NSW 156204).

iNaturalist observations (https://inaturalist.ala.org.au/)**:** 67741566, 143698210, 148551738.

Key to similar species

These two newly described species are moderately vigorous subshrubs or vines, scrambling or climbing in habit, like various other species in the genus. A key is provided to these and species of broadly similar habit in eastern and northern Australia.

1. Distal third of leaf with margins straight or concave in outline; apex of leaf long-acute to long-cuspidate (a 'drip tip') 2
1: Distal third of leaf with margins convex in outline; apex of leaf obtuse or emarginate (may be apiculate) or short-acuminate to acute 4
2. Fruiting perianth succulent, whitish to yellow-brown ..... ***M. gunnii***
2: Fruiting perianth not succulent, greenish 3
3. Nut subglobose, 2–2.5 mm long, ± shining, finely granulate, scarcely to strongly rugose; petioles and veins on abaxial leaf surface usually white-scaberulous ..... ***M. gracillima***
3: Nut broad-elliptical to ovate in outline, trigonous in cross-section, 3–3.5 mm long, dull, strongly transversely rugose; petiole and veins on abaxial leaf surface smooth ..... ***M. zippelii***
4. Nut smooth or minutely granulate ..... ***M. adpressa***
4: Nut transversely rugose or tuberculate 5
5. Fruiting perianth strongly succulent; leaves with fine secondary rugulose to linear ornamentation at least on adaxial surface (seen clearly at 25× magnification); leaf margin recurved or occasionally undulate ..... ***M. gunnii***
5: Fruiting perianth ± fleshy but not strongly succulent; leaves without secondary ornamentation; leaf margin flat, not recurved 6
6. Nut trigonous in cross-section; strong climber to 10 m high ..... ***M. zippelii***

6: Nut globose to broadly trigonous in cross-section; semi-erect subshrub, scrambler or climber to 4 m high **7**

7. Nut tuberculate with tubercles forming 6 longitudinal ridges; leaf margins strongly crisped; petiole and veins on abaxial surface of leaf white-scaberulous..... ***M. costata***

7: Nut strongly transversely rugose and granulate; leaf margins not or scarcely crisped; petiole and veins on abaxial surface of leaf smooth ..... ***M. arnhemica***

Muehlenbeckia diclina (F.Muell.) F.Muell., *Fragmenta* 4: 131 (1864).

Muehlenbeckia stenophylla F.Muell. has sometimes been considered a synonym of *M. diclina* (F.Muell.) F.Muell. but morphological differences in habit (Figure 5), anther size and fruits (see Figure 6 for nut features and see key below), habitat differences and geographic separation led us to the conclusion that the former should be recognised as a subspecies of the latter. The relevant combination is made here and lectotypes are selected.

The two subspecies have discrete distributions (Figure 7): *M. diclina* subsp. *stenophylla* (F.Muell.) K.L.Wilson & Makinson occurs in the mountains of eastern Victoria and south-eastern New South Wales, while the typical subspecies is inland, from Pooncarie in south-western New South Wales to north-western Victoria and the northern Eyre Peninsula in South Australia, with a disjunct occurrence in southern Western Australia as far west as the Hyden area. Both subspecies are fire-ephemerals and have been observed to reshoot after fire, but the relative frequency of resprouting versus seed reproduction is unknown. The two subspecies can be distinguished as follows:

1. Nut broadly trigonous to subglobose; nut surface ± shining, smooth or with faint irregular transverse ridges; anthers 0.6–1.0 mm long; erect to spreading subshrub, stems spreading to erect, leaves ascending to spreading ..... ***M. diclina*** subsp. ***diclina***

1: Nut trigonous to triquetrous; nut surface ± dull, irregularly but strongly rugose with both transverse and longitudinal ridges; anthers 0.7–1.5 mm long; virgate subshrub with stems and leaves usually more or less strongly erect..... ***M. diclina*** subsp. ***stenophylla***

Muehlenbeckia diclina (F.Muell.) F.Muell. subsp. ***diclina***

Polygonum diclinum F.Muell., *Trans. Philos. Soc. Victoria* 1: 23 (1855); *Hooker's J. Bot. Kew Gard. Misc.* 8: 203 (1856).

Muehlenbeckia diclina (F.Muell.) F.Muell., *Fragmenta* 4: 131 (1864).

Muehlenbeckia polygonoides F.Muell., *Fragmenta* 5: 73, 91 (1865); Ewart, *Pl. Indig. Victoria* 2: 17, t.80 (1910); *nom. illeg.*

Type citation: 'On shifting sandhills at the junction of the Murray and Murrumbidgee, and rarely at the Mitta Mitta.'

Type: Victoria or New South Wales?: Murray River, *F. Mueller,* 1853; lecto (here designated) ♂, MEL 1552392; possible isolecto K000831384, MEL 1550774 (♂, with nuts in packet), YU 068981 (image seen).

Typification: There is no specimen in MEL that bears full protologue details. The lectotype is chosen because it is annotated by Mueller, bears part of the protologue information, and has a better specimen (leaves and flowers still attached to the branch) than MEL 1550774, in which most of the leaves and all of the flowers have become detached from the branch and are in a packet attached to the specimen (along with nuts presumably from another collection). The lectotype is annotated as 'unicum' by Sonder, indicating that it was a unique sheet in Sonder's herbarium. The possible isolectotypes may represent material kept by Mueller when he sent the specimen to Sonder.

We have not seen any *Muehlenbeckia* specimens labelled as coming from the Mitta Mitta area, which is in Gippsland. Specimens from that area would be the other subspecies.

The combining author for the combination under *Muehlenbeckia* has previously been taken as Druce. However, the statement by Mueller (1864: 131) is adequate to make the new combination. There is a printing mistake in that statement ('P.' is substituted for 'M.' in the new combination), but Mueller's statement is unambiguous and his intention is supported by the index (Mueller 1864: 191), where the name is given as '*Muehlenbeckia diclina*'.

Distribution and habitat: This subspecies is found from Pooncarie in south-western New South Wales to north-western Victoria (the Lowan Mallee Bioregion; Walsh 1996) and the northern Eyre Peninsula in South Australia, with a disjunct occurrence in southern Western Australia as far west as the Hyden area (Figure 7). Associated with mallee woodland and mallee-heath on old, fixed sand dunes, on deep sandy or loamy soils; most obvious after fire disturbance.

Notes: Differs from subspecies *stenophylla* in the nut features mentioned in the key (also see Figure 6), and in being an erect (but not virgate) to spreading subshrub. The fruiting perianth is said to be less succulent in this subspecies (Moore & Betche 1893: p. 123), but more field observations are needed to confirm this.

Selected specimens seen: Western Australia: Hyden, *A.E. Marsh s.n.*, 10 June 1936 (vegetative, PERTH); Camp 68 near Fraser Range, *R. Helms s.n.,* Oct 1891 (♂, NSW 156410), Nov 1891 (♂, MEL 1550784, NSW 156411).

South Australia: Kyancutta, *B. Copley 2601*, 26 July 1969 (♂, AD 96937261, B n.v., G n.v.).

New South Wales: 50 km NE of Pooncarie, *W.E. Mulham 811,* Nov 1974 (♀, CANB 650214, MEL 1590218, NSW 234161); 6 miles [c. 10 km] E of Manfred on road to Manfred Range (SW of Ivanhoe), *T.M & J.L. Whaite 2073*, 16 Nov 1956 (♀, NSW 252074).

Victoria: Northern Plains, Sunset Country, 3 km W of Gypsum Plant along abandoned railway line towards Rocket Lake, *M.D. Crisp 3397* (♂, AD 97925320, CBG 7706509, MEL 560268), *3398* (♀, AD 97925328, CBG 7706510, MEL 560269).

iNaturalist observations (https://inaturalist.ala.org.au/)**: New South Wales:** 179787720.

South Australia: 141494607, 62286380, 58931172.

Victoria: 157998107, 47717604, 47702792, 47700801.

Figure 5. *Muehlenbeckia diclina*: subspecies *diclina* (A, regrowth after fire; B, leaf with basal lobe on young regrowth; Murray-Sunset National Park, Victoria) and subsp. *stenophylla* (C, habit; D, leaves and male flowers; McKillops Road, Victoria). Photographs by Tanja Schuster (A, B) and Karen Wilson (C, D).

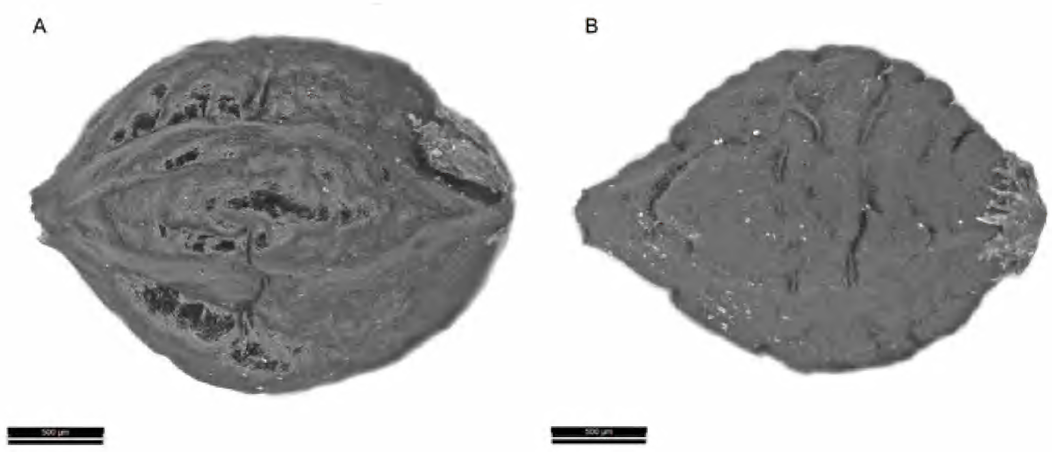

Figure 6. Fruits of A, *Muehlenbeckia diclina* subsp. *diclina* (NSW 252074); B, *M. diclina* subsp. *stenophylla* (NSW 667463), with flattened remnants of styles present. Scale bar = 500 µm.

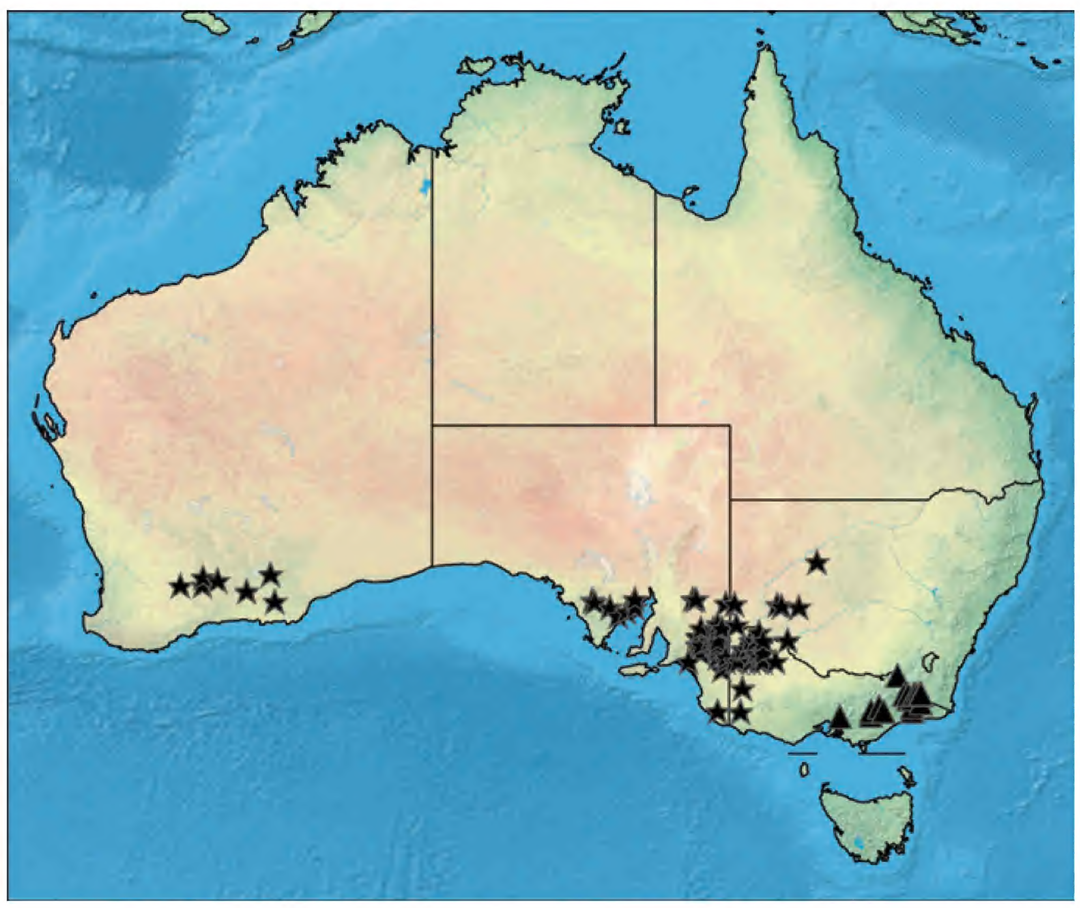

Figure 7. Distribution of *Muehlenbeckia diclina*: subsp. *diclina* (stars) and subsp. *stenophylla* (triangles).

Muehlenbeckia diclina subsp. ***stenophylla*** (F.Muell.) K.L.Wilson & Makinson, comb. et stat. nov.

Muehlenbeckia stenophylla F.Muell., *Fragmenta* 1: 138 (1859).

Type citation: 'In rupibus montium ad flumen McAllister River terrae Gipps Land, altitudine circiter 3000' [feet].'

Type: Victoria: Rocky summits of mountains 3000 ft [c. 1000 m] high on the McAllister [Macalister River], Gippsland, *F. Mueller*; lecto (here designated) ♀, MEL 1530776; probable isolecto B, E, FI, K 000831383, MEL 1550775.

Muehlenbeckia diclina subsp. Gippsland (R.O. Makinson 1007).

Typification: The lectotype is the only sheet in MEL that has a label with full locality information in Mueller's script and is chosen for this reason (the specimen is rather depauperate but adequate, with a few flowers and leaves attached to the branch and others in a packet). Its label is annotated with a pencilled 'B' on the reverse, indicating that it was seen by Bentham. The probable isolectotype MEL 1550775 bears similar material to the lectotype and has a label with the same information but written in a very neat and large hand, suggesting that this may have been a sheet for public display. The other sheet, MEL 1550969, has a similar specimen but is merely labelled (in Mueller's script) as coming from Gippsland.

Distribution and habitat: Occurs in montane areas of far south-eastern New South Wales and eastern Gippsland, Victoria, at least as far south as Licola (Figure 7). Associated with rocky outcrops or occasionally in forests, to an altitude of at least 1,200 m.

Notes: Differs from the typical subspecies in nut characters as given in the key (also see Figure 6), and in being a more strongly virgate subshrub. Both subspecies tend to be strongly glaucous when young but become less so with maturity. The typical subspecies may be less glaucous than subspecies *stenophylla*, but more field observation is needed to confirm this. Similarly, the fruiting perianth is said to be more succulent in subsp. *stenophylla* (Moore & Betche 1893: p. 123), but more field observations are needed to confirm this.

Selected specimens seen: New South Wales: Byadbo Range, *A.B. Costin s.n.*, Aug 1949 (vegetative, NSW 156413); Merambego [Murrumbuco] 28 miles [45 km] from Delegate, *W. Forsyth s.n.*, May 1908 (♂, NSW 156412); Merambego Fire Trail, c. 1 km E from ford over tributary of Byadbo Creek, *J. Miles 1307*, 4 Feb 2013 (♀, NSW 879966).

Victoria: Hanging Rock at escarpment of ridge running N from summit of World End spur, c. 2.9 km SE of Mount Hamilton, *D.E. Albrecht 3233 & S.J. Forbes,* 15 Feb 1986 (♀, AD 99119350, CBG 8906194, HO, MEL 1560695, NSW 667463); Buchan River Gorge below Native Dog Plain, *A.C. Beauglehole 35946*, 9 Jan 1971 (♀, MEL 2224743); Yarra Range, *A.C. Beauglehole* 78056, 7 Oct 1984 (MEL 1550971, NSW 667467); near McKillops Bridge, Upper Snowy River, *L. Costermans s.n.,* 7 Jan 1977 (♀, MEL 599820); c. 6 km (direct) WNW of Dellicknora, c. 6.5 km NW along McKillops Bridge road from junction with Dellicknora road, *R.O. Makinson 1007 & P. Carmen,* 7 Dec 1991 (♂, CBG 9107031, K, MEL 275492, NE, NSW 453383, US); Reedy River valley, below Brumby Point, Nunniong Plateau area, *J.H. Willis s.n.,* 13 Nov 1964 (♂, MEL 502526, NSW 667465); McKillops Road, c. 6.5 km NW of Dellicknora turn-off, *K.L. Wilson 10497 & A. Wilson*, 31 Dec 2008 (♂, CANB, K, MEL 2334144, NSW 785563, NY).

iNaturalist observations (https://inaturalist.ala.org.au/)**: Victoria:** 139746193, 74115901, 73991868, 67563565, 66896237, 66649374.

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References

Brandbyge, J (1992) The genus *Muehlenbeckia* (Polygonaceae) in South and Central America. *Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie* 114: 349–416.

Classen-Bockhoff, R, and Bull-Hereñu, K (2013) Towards an ontogenetic understanding of inflorescence diversity. *Annals of Botany* 112: 1523–1542. DOI

Endress, PK (2010) Disentangling confusions in inflorescence morphology: patterns and diversity of reproductive shoot ramification in angiosperms. *Journal of Systematics and Evolution* 48: 225–239. DOI

Hunter, JT (1995) Some observations on the fire responses of two rare species in the Girraween and Bald Rock National Parks. *Queensland Naturalist* 33(5–6): 146–147.

Hunter, JT, and Clarke, PJ (1998) The vegetation of granitic outcrop communities on the New England Batholith of eastern Australia. *Cunninghamia* 5: 547–618. URL

Hunter, JT, Fallavollita, E, and Hunter, VH (1998) Observations on the ecology of *Muehlenbeckia costata* ms. (Polygonaceae), a rare fire ephemeral species occurring on the New England Batholith of north-eastern New South Wales and southern Queensland. *The Victorian Naturalist* 115(1): 9–17. URL

Hunter, JT (2011) *Vegetation and floristics of the Pilliga East State Conservation Area, Willala Aboriginal Area, Pilliga Nature Reserve and the Ukerbarley addition*. Unpublished report to the NSW Department of Environment, Climate Change and Water. DOI

IUCN (2022) 'IUCN Red List categories and criteria'. (International Union for Conservation of Nature: Gland, Switzerland)

Mueller, FJH von (1864) *Fragmenta phytographiae australiae* 4. (Government Printer: Melbourne) URL

NSW Office of Environment and Heritage (2013) *Willala Aboriginal Area plan of management*. (Office of Environment and Heritage: South Sydney)

NSW Office of Environment and Heritage (2023) *Scrambling Lignum – profile*. URL (accessed 7 July 2023)

Russell-Smith, J (1986) *The forest in motion: exploratory studies in western Arnhem Land, northern Australia*. PhD thesis (Australian National University: Canberra)

Schuster, TM, Wilson, KL, and Kron, KA (2011) Phylogenetic relationships of *Muehlenbeckia*, *Fallopia*, and *Reynoutria* (Polygonaceae) investigated with chloroplast and nuclear sequence data. *International Journal of Plant Science* 172(8): 1083–1066. DOI

Short, PS (2011) Polygonaceae. Pp. 1–6 in Short, PS, and Cowie, ID (eds), *Flora of Darwin region* vol. 1 (online edition). URL (accessed 26 April 2021)

Shorthouse DP (2010) SimpleMappr, an online tool to produce publication-quality point maps. [Retrieved from URL (accessed 20 June 2023)

Walsh, NG (1996) Polygonaceae. Pp. 272–295 in Walsh, NG, and Entwisle, TJ (eds) *Flora of Victoria vol. 3, Dicotyledons Winteraceae to Myrtaceae*. (Inkata Press: Melbourne)

Wilson, KL (1990) Polygonaceae. Pp. 278–293 in Harden, GJ (ed.), *Flora of New South Wales*, vol. 1. (University of NSW Press: Sydney)

BOTANIC GARDENS OF SYDNEY

Telopea

Journal of Plant Systematics

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The Australian blood lime described and named: *Citrus* × *sykesii* Mabb. (Rutaceae-Aurantioideae-Aurantieae)

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Abstract

The Australian blood lime of commerce is formally described and named *Citrus* × *sykesii* Mabb., hybrida nova.

Introduction: The blood lime of commerce

Increasingly seen in supermarkets in Australia, as well as in farmers' markets, besides being more and more grown by specialist nurseries supplying home gardens, is a citrus fruit generally known as '(Australian) blood lime', a cultivar originally named 'Australian Blood' (Sykes 2002). It was selected by Stephen Sykes of the CSIRO Plant Industry (Horticultural Unit) at Merbein (near Mildura), Victoria in 1990 (Sykes 2002), from hybrid seedlings resulting from open pollination crosses between a red finger lime cultivar (*Citrus australasica* F.Muell. (Sanguinea Group)) pollen-parent, and a monoembryonic seedling of Rangpur lime (*Citrus* × *otaitensis* (Risso) Risso 'Rangpu'; '*C. limonia*', '*C. taitensis*' auctt.). Rangpur lime is itself of hybrid origin, being a cross between the citron (*C. medica* L.) and an orange (*C.* × *aurantium* L., i.e. *C. reticulata* Blanco [mandarin] × *C. maxima* (Burm.) Merr. [pomelo]) – see Mabberley (2022), Mabberley & Xu (2022).

Seeds from the maternal parent tree, established next to a row of pigmented finger limes, were germinated in a greenhouse and those seedlings with finger-lime characteristics were selected and grown in the citrus orchard: following the closure of the Merbein site by CSIRO in 2011, these trees were lost and no herbarium voucher specimens were preserved (Stephen Sykes, pers. comm., 20 January 2024). Fortunately, photographs were taken of some of the batch of hybrid seedlings from which 'Australian Blood' was selected (Fig. 1).

Mabberley DJ (2024) The Australian blood lime described and named: *Citrus* × *sykesii* Mabb. (Rutaceae-Aurantioideae-Aurantieae). *Telopea* 27: 11–13.
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Fig. 1. *Citrus* × *sykesii* seedlings raised at CSIRO Merbein, Victoria by Stephen Sykes; 'Australian Blood' at far right. Photo: 4 June 1990, by Ted Lawton (CSIRO photographer, deceased). © CSIRO.

It was only the third interspecific hybrid involving *Citrus australasica* to be raised, the first being *C.* × *oliveri* Mabb., the sunrise lime (*C. australasica* × *C.* × *microcarpa* Bunge, the calamondin, a cross between the kumquat, *C. japonica* Thunb., and *C. reticulata*) first synthesised in USA (as faustrimedin) around 1911, followed by *C.* × *virgata* Mabb. (*C. australasica* × *C. australis* (Mudie) Planch. [dooja, Australian lime]) at the Royal Botanic Garden Sydney in the 1920s (Mabberley 1998).

The new crop needs a botanical name, which is here provided, complete with a full description based on living material grown at The Australian Botanic Garden, Mount Annan, Sydney, Australia.

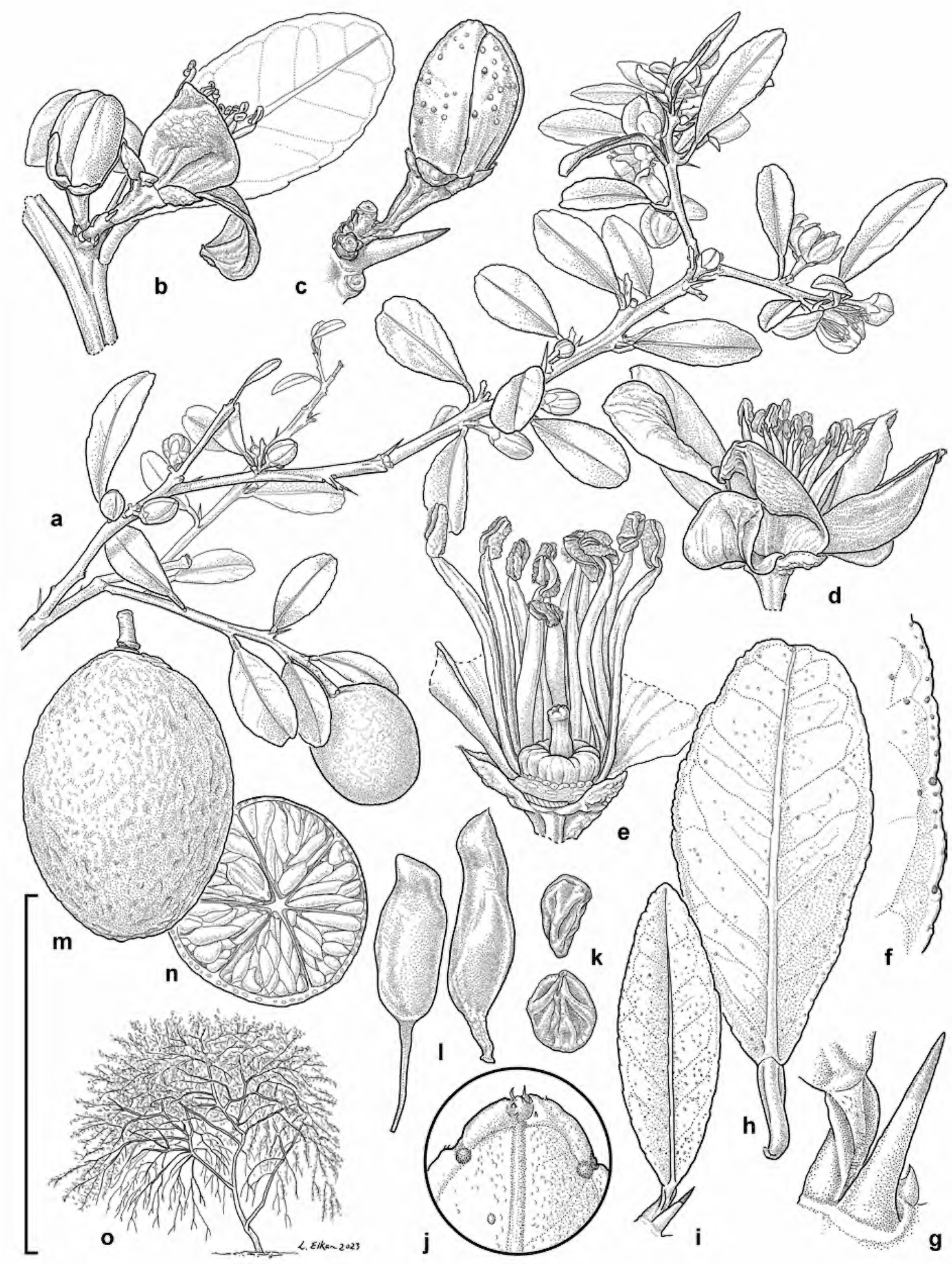

Fig. 2. *Citrus* × *sykesii* Mabb. a. fertile branchlet; b. inflorescence with bud and flower, lateral view; c. flower bud and spine detail; d. flower, lateral view; e. detail of flower showing pistil and stamens with some petals & stamens removed; f. detail of leaf margin; g. petiole and spine detail; h. leaf abaxial surface; i. leaf adaxial surface; j. leaf-tip detail; k. seeds - lateral and front; l. vesicles, showing variation in shape; m. fruit; n. fruit cross-section; o. habit showing marcescent spiny branches. Voucher: *J.M. Cohen & D.J. Mabberley* 2023/112 (NSW, holotype). Scale bars: a = 6 cm; b, h & i = 2 cm; c, d = 1.5 cm; e, f, k & l = 1 cm; g = 0.6 cm; j = 0.3 cm; m & n = 4 cm; o = 200 cm. Illustration by Lesley Elkan.

Citrus × sykesii Mabb., **hybrida nova** (*C. australasica* F.Muell. × *C.* × *otaitensis* (Risso & Poit.) Risso [*C. medica* L. × *C.* × *aurantium* L. (*C. reticulata* Blanco × *C. maxima* (Burm.) Merr.)]). Fig. 1.

Type: Australia [cultivated], New South Wales, Australian Botanic Garden, Mount Annan, Bed 256 (planted 2011), 26 September 2023, *J.M. Cohen & D.J. Mabberley* 2023/112 (holo: NSW 1132536; iso to be sent to: ATH, BRI, CANB, MEL, K, MO, NY, P).

Somewhat dome-shaped, glabrous, armed, andromonoecious treelet, c. 1.5 m tall, 1.5 m diam. with marcescent spiny twigs on branches; living branchlets with dense foliage bearing flowers and some of previous season's fruits simultaneously. Trunk branched low down, c. 7 cm. diam.; bark smooth, mid-brown. Foliage planar in somewhat drooping sprays. Leaves 18–30 mm long, 6–10 mm wide, narrowly elliptic to obovate, glossy, leathery, dark green adaxially (reddish when young), paler abaxially; lamina weakly jointed, margin subentire to weakly crenulate or serrulate especially distally; apex acute to emarginate; lateral veins c. 5 or 6 on each side, looped at margin; petiole c. 6 mm long, very narrowly winged. Spines 4–15 mm long, straight, axillary. Flowers solitary, rarely in pairs, pink in bud, 3–5(6)-merous, strongly scented (reminiscent of *Convallaria majalis* L., Asparagaceae) opening both above and below foliage; pedicel to 4 mm long; bracteole 1, c. 1 mm long. Calyx lobes 3 or 4, 2 mm long, 1.8 mm wide, triangular, sometimes subtending a whorl of up to 3 reduced petals; petals 8 mm long, 5 mm wide, broadly ovate, white, usually with pale pink streaks on outer face; stamens 15–20, free or weakly adnate to petals, filaments 4–5 mm, long, white, anthers c. 1.5 mm long, bright yellow; disk c. 0.3 mm tall, cushion-like; ovary 6-locular, style 1.5–2 mm with clavate style-head c. 0.5 mm diam., yellow. Fruit spherical-ovoid, c. 3 cm long, subtended by weakly accrescent disk, rugulose, orange-red to purplish, 6-locular, resinous-smelling when cut; pericarp c. 1.5 mm thick, vesicles 3–4 mm long, oblong-apiculate, pink, acid-tasting; seeds 1 per locule, 4–5 mm across, irregularly subglobose to weakly rostrate, mono-embryonic, cotyledons green.

Etymology: It is a pleasure to celebrate the research of Stephen Sykes (b. 1954 in Merton Park (London), England) in naming one of his citrus hybrids after him.

Note: The cultivated specimen from which the type collection was made was sourced from the Mount Burrell Cultural Garden, in 2008 as *Citrus* 'Australian Blood'.

This description is based on authentic material ('Australian Blood'); some fruits offered for sale in the trade are scarcely red. Whether such cultivars of *C.* × *sykesii* are somatic mutants or other crosses between *C. australasica* and *C.* × *otaitensis* remains to be ascertained (Figs. 1, 3).

Fig. 3. Commercial *Citrus* × *sykesii* in a supermarket (Photo: Joel Cohen).

Stephen Sykes crossed 'Australian Blood' with 'Nules' (*C.* × *aurantium* (Tangerine Group)) and selections were made. Of these, a "red-fruited selection was propagated further and gained some interest from various parties" (Stephen Sykes pers. comm. 26 January 2024) and may enter commerce as another cultivar of *Citrus* × *sykesii*.

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The author is grateful to Joel Cohen (Tondoon Botanic Gardens, Queensland) for helping with the collecting and examination of the type material, when he was working for Botanic Gardens of Sydney, and for providing Fig. 3; to Lesley Elkan (NSW) for the superb line illustration (Fig. 2); to John Siemon (NSW) for facilitating the collecting work and, especially, to Stephen Sykes (South Australia) for looking over an early draft of the paper, besides providing information on the original and subsequent crosses, as well as Fig 1.

References

Mabberley DJ (1998) Australian Citreae with notes on other Aurantioideae (Rutaceae). *Telopea* 7: 333–344. PDF

Mabberley DJ (2022) A classification for edible citrus: an update, with a note on *Murraya* (Rutaceae). *Telopea* 25: 271–284. DOI

Mabberley DJ, Xu Q (2022) (2925) Proposal to conserve the name *Citrus reticulata* Rutaceae) with a conserved type. *Taxon* 71: 1123–1124. DOI

Sykes S (2002) *Citrus* hybrid. Hybrid Finger Lime. *Plant Varieties Journal* 15(4): 19–20. PDF

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Leionema paulii (Rutaceae), a new, range-restricted endemic species from south-eastern New South Wales, Australia

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Abstract

Leionema paulii G.P.Phillips (Rutaceae), a newly recognised species of restricted distribution from montane south-eastern New South Wales is here described. It is compared with the morphologically similar *L. phylicifolium* (F.Muell.) Paul G.Wilson, *L. ceratogynum* N.G.Walsh and *L. lachnaeoides* (A.Cunn.) Paul G.Wilson. The distribution, habitat and proposed conservation status for the new taxon are presented, and a modified key to the species of *Leionema* found in New South Wales is also included. *Leionema paulii* was previously recorded as a disjunct population of *L. phylicifolium* that was previously not represented by any herbarium specimens. This highlights the opportunity for further taxonomic discovery through the collection and analysis of specimens from more disjunct and discrete populations in genera that contain large numbers of narrow-range endemics.

Introduction

Leionema (F.Muell.) Paul G.Wilson (Rutaceae) is a widespread genus with many narrow-range endemics, with 28 of the 29 currently described species endemic to eastern Australia, and one species residing in New Zealand (Wilson 2013; Copeland and Telford 2018; Alvarez and Duretto 2019; Telford and Bruhl 2020). New South Wales is a particularly diverse region for *Leionema*, with over 60% of the 18 species known to occur in the state being endemic (Alvarez and Duretto 2019; Telford and Bruhl 2020). *Leionema phylicifolium* (F.Muell.) Paul G.Wilson is a species distributed across the alpine region of eastern Victoria and south-eastern New South Wales. It is one of only four species of *Leionema* on mainland Australia that can have a white-puberulous indumentum on the leaf abaxial surface, the others being the closely related *L. dentatum* (Sm.) Paul G.Wilson, *L. lachnaeoides* (A.Cunn.) Paul G.Wilson and *L. ceratogynum* N.G.Walsh (Wilson 1970; Walsh 2004). *Leionema phylicifolium* shows significant variation across its discontinuous range, with distinct forms that can be distinguished by characters such as indumentum of the leaf abaxial surface and ovary, and this morphological variation was previously highlighted by Wilson (1970) as possibly sufficient to warrant further taxonomic distinction.

A number of narrow-range taxa within *Leionema* that are new to science have been formally described in recent times. This has mostly come about through the recognition of distinct, morphologically differentiated populations either observed in the field, or through examination of existing herbarium specimens (Walsh 2004; Bell and Walsh 2015; Copeland

Gavin P. Phillips (2024) *Leionema paulii* (Rutaceae), a new, range-restricted endemic species from south-eastern New South Wales, Australia. *Telopea* 27: 15–21. doi:10.7751/telopea17123

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and Telford 2018; Telford and Bruhl 2020). This has resulted in several new subspecies being recognised within existing species where disjunct populations with fine morphological differences occur, as is the case with *L. bilobum* (Lindl.) Paul G.Wilson (4 subspecies, Duretto *et al.* 2006) and *L. lamprophyllum* (F.Muell.) Paul G.Wilson (4 subspecies, Anderson 1999; Bell and Walsh 2015). It is also the case where different species have been raised where morphological differences are more pronounced among populations, such as the separation of *L. ceratogynum* from *L. phylicifolium* (Walsh 2004).

In October 2019, whilst conducting fieldwork in the ranges of the eastern Monaro region between Bombala and Bega in south-eastern New South Wales, a population of what initially appeared to be *Leionema phylicifolium* was noted by the author. It was found growing on the edge of a montane swamp, growing only in sphagnum moss at approximately 930 m elevation. Despite several existing observational records from the same location, no specimens from the site have ever been lodged at herbaria. Voucher specimens were subsequently taken and compared with collections at the National Herbarium of New South Wales. This examination provided evidence that these plants differed morphologically from all other collections of *L. phylicifolium*. Most notable was the distinctive glandular-verrucose adaxial surface of the foliage (*cf.* smooth upper surface), bullate-verrucose cocci (*cf.* smooth cocci), the sphagnum bog habitat (*cf.* stream bank or ridgetop habitat), and the minutely tuberculate seed coat (*cf.* smooth). Thus, the hypothesis was formed that this newly sampled population represented a distinct and undescribed taxon which is reproductively and geographically isolated, with the nearest known *Leionema* populations being stands of *L. phylicifolium s. str.* and *L. ceratogynum*, both approximately 45 km to the north. This newly discovered species is here described as *Leionema paulii* G.P.Phillips.

Materials and methods

All collections of *Leionema phylicifolium,* as well as the closely related species *L. ceratogynum* and *L. lachnaeoides* held at the National Herbarium of New South Wales, along with the field collections of the new entity were examined, as well as descriptive data pertaining to *L. phylicifolium* (Wilson 1970). The lectotype and paralectotypes of *L. phylicifolium* held by the National Herbarium of Victoria (MEL0004888A, MEL0040887A and MEL0004886A) were observed using images available through the Australian Virtual Herbarium (AVH 2024). Comparisons were made of the morphological features between specimens and populations across all the related species' ranges, and distinguishing features were measured and detailed to compile the description for *L. paulii*. Measurements and terminology follow Wilson (1970, 1998) and Walsh (2004). Material was collected under NSW Scientific Licence SL100569 (issued to the Botanic Gardens Trust, Royal Botanic Gardens, Sydney).

There have recently been efforts to standardise the application of subspecies and species rank within Rutaceae tribe Boroniae, with the phenetic species concept having been traditionally applied in Australian Rutaceae (Forster 2003, 2005; Telford and Bruhl 2020). Species have been recognised in this system when populations show discontinuities in the variation of two or more independent morphological characters, with subspecies rank applied when populations differ in few, minor characters, and intermediate morphologies exist (Forster 2005). These criteria are followed here in assessing the taxonomic rank of *Leionema paulii*, consistent with previous studies (Forster 2003, 2005; Telford and Bruhl 2020).

Assessment of the conservation status of *Leionema paulii* was undertaken using criteria, terms and definitions outlined in IUCN (2022).

Taxonomy

Leionema paulii G.P.Phillips, ***sp. nov.***

Type: AUSTRALIA: New South Wales: Southern Tablelands: South East Forest National Park, Nunnock Swamp, c. 35 km NE of Bombala, 26 Oct 2019, *G.P. Phillips 944 & D. Whitton* (holotype: NSW 1059870; isotypes: MEL, CANB).

Shrub, dense, low and much branched to *c.* 1 m high and wide; branchlets angled by leaf decurrencies when young, bearing prominent, wart-like leaf scars when older, sparsely to densely stellate-puberulous; hairs with rays to *c.* 0.1 mm long. *Leaves* simple, alternate; petiole flattened, erect, *c.* 1–1.5 mm long; lamina lanceolate to oblong-elliptic to oblanceolate, (4–)8–12(–14) mm long, 1–2 mm wide; adaxial surface distinctly glandular-verrucose with glands *c.* 0.5 mm across, with scattered stellate hairs; abaxial surface glandular-verrucose often with scattered oil glands protruding through a dense indumentum of white stellate hairs, sparsely to densely stellate-puberulous on raised midrib; margin revolute, often appearing somewhat crenate due to the raised oil glands; apex obtuse; base tapering to petiole. *Inflorescences* 3-flowered, axillary along distal 5–10 cm of branch. *Peduncles* (1–)2–4(–5) mm long, glabrous to glabrescent with scattered stellate hairs, flattened, with 2 terminal, ovate, stellate-puberulous bracts *c.* 1 mm long. *Pedicels* (1–)2–3 mm long, glabrous, terete and fleshy, becoming strongly ridged when dry, glandular-verrucose, with 2–3 decussate pairs of narrowly ovate bracteoles that are *c.* 0.5 mm long in the proximal half. *Calyx* obturbinate, *c.* 1 mm long, glandular-verrucose, lobes deltoid and imbricate with a tuft of stellate hairs at the apex. *Petals* 5, valvate in bud, narrow-elliptic to narrow-oblanceolate, 4–5 mm long, pale yellow, glabrous, glandular-verrucose with oil glands on abaxial surface often notably darker than petal lamina in colour, not persistent in fruit. *Stamens* 10, 4–6 mm long, exerted beyond the petals; anthers cordate-orbicular, *c.* 1 mm long. *Gynophore* terete, to *c.* 0.5 mm long. *Ovary* subglobose, *c.* 1.5 mm long, white stellate-puberulous; carpels 5, fused for most of length, apex with a sterile knob-like process; style slightly shorter to slightly longer than stamens, 4–6 mm long, terete, glabrous; stigma minute. *Cocci* 5 or less due to abortion, spreading about the central axis; dehiscent, ellipsoidal, *c.* 3–4 mm long, 1.5–2 mm wide, distinctly bullate-verrucose, densely stellate-puberulous, hairs with rays to *c.* 0.1 mm long, wearing down with age; sterile apical process 1–2 mm long, obtuse conical. *Seed* D-shaped to subreniform, 2–3 mm long, dorsal edge rounded, testa glossy dark brown, minutely tuberculate; raphe circular to ovate, sub-basal, *c.* 1.5 mm long and wide, held obliquely away from the testa by the hilum at point of attachment. (Figs 1–3).

Fig. 1. *Leionema paulii*. A. Typical flowering branch. B. Leaf adaxial surface showing the distinctive glandular-verrucose surface. C. Leaf abaxial surface. Voucher: *G.P. Phillips 944* (NSW). Scale bars: A, 12 mm; B, 2 mm; C, 3.5 mm.

Fig. 2. *Leionema paulii* at the type location, South East Forest National Park near Bombala, New South Wales.

Additional Specimens Examined: AUSTRALIA: New South Wales: Southern Tablelands: South East Forest National Park, Nunnock Swamp, on isthmus on western side, 20 Dec 2020, *G.P. Phillips 1349 & J.M. Cohen* (NSW, MEL, CANB, BRI, AD).

Diagnostic characters: *Leionema paulii* is morphologically most similar to *L. phylicifolium, L. ceratogynum* and *L. lachnaeoides*. However, the vegetative, flower and fruit differences are great enough that it is easily distinguishable from all three species in the field (Table 1).

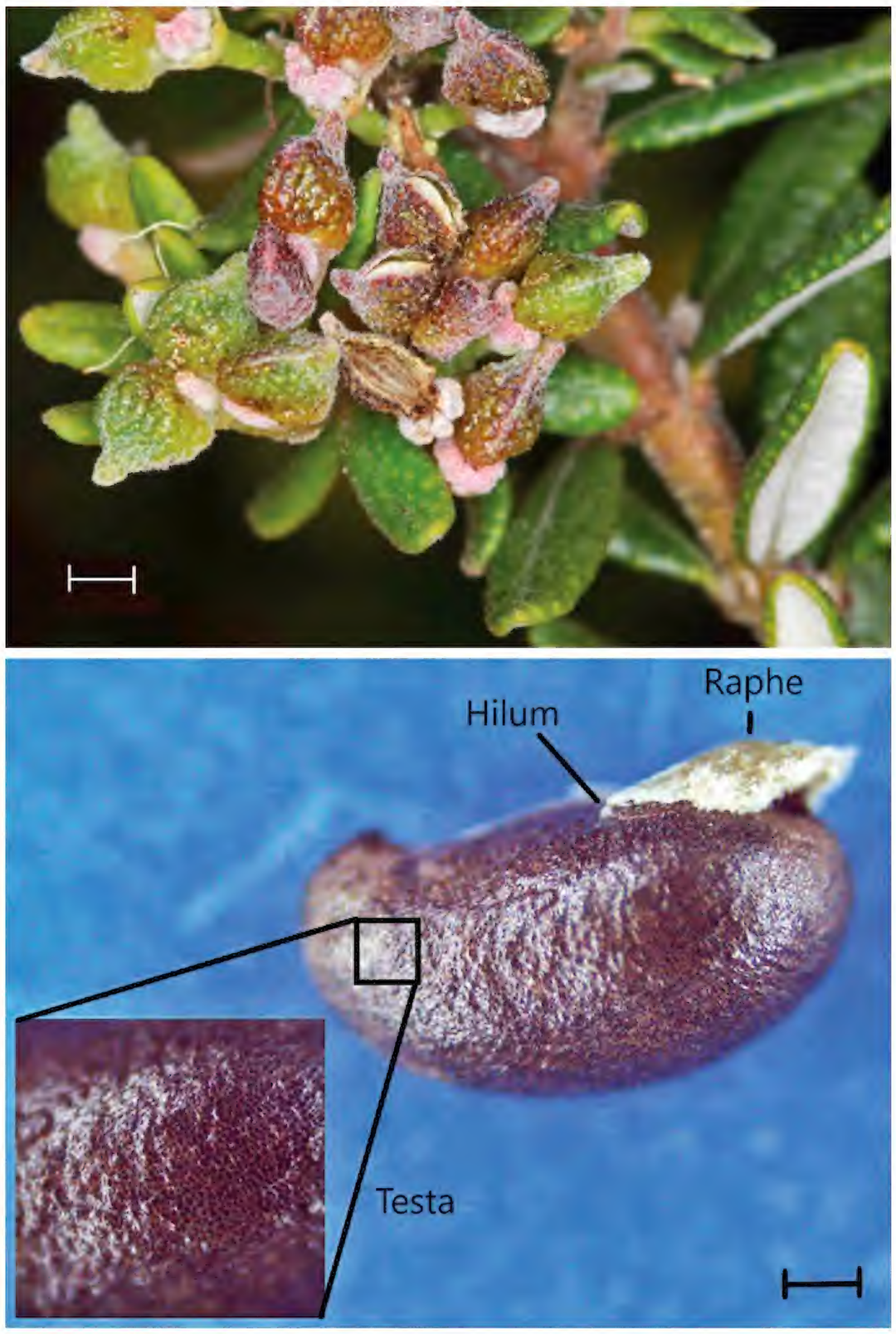

Fig. 3. *Leionema paulii*. A. Fruits showing the bullate-verrucose cocci. Voucher: *G.P. Phillips 1349* (NSW). Scale bar: 2 mm. B. Seed showing the minutely tuberculate surface (inset) and raphe suspended at an oblique angle away from the testa. Scale bar: 400 µm; inset magnification ×250.

Distribution: *Leionema paulii* occurs in the South Eastern Highlands Bioregion (DAWE 2012) where it is currently known only from a single population within South East Forest National Park, north-east of Bombala on the Southern Tablelands of New South Wales (Fig. 4).

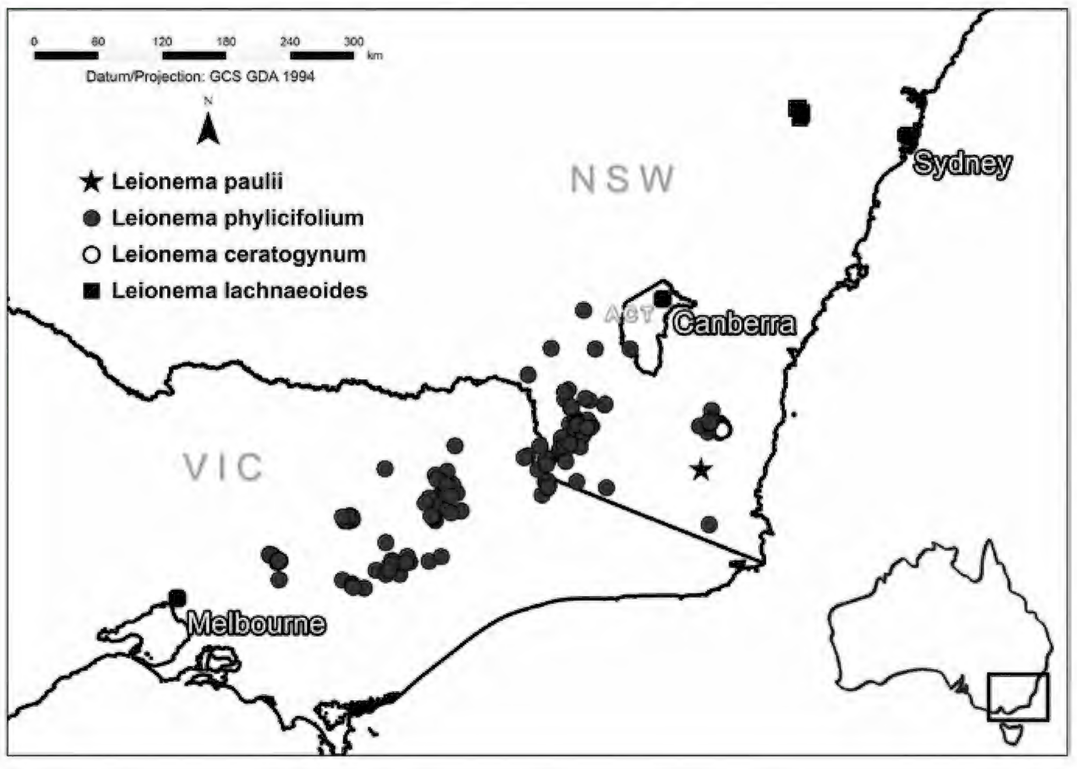

Fig. 4. Distribution of *Leionema paulii*, *L. phylicifolium*, *L. ceratogynum* and *L. lachnaeoides* in south-eastern Australia. Map generated in ArcGIS (ESRI 2015).

Table 1. Comparison of key diagnostic features of *Leionema paulii*, *L. phylicifolium* (sensu Wilson 1970), *L. ceratogynum* (sensu Walsh 2004) and *L. lachnaeoides* (sensu Wilson 1970 and Walsh 2004).

Character	*L. paulii*	*L. phylicifolium*	*L. ceratogynum*	*L. lachnaeoides*
Leaf adaxial surface	distinctly glandular-verrucose	smooth	minutely scabridulous	minutely scabridulous
Leaf abaxial surface	glandular-verrucose	smooth	smooth	smooth
Peduncles	(1–)2–4(–5) mm long, glabrous to glabrescent with stellate hairs	1–3 mm long, glabrous	0–1 mm long, glabrous to glabrescent with stellate hairs	1.5 mm long, sparsely stellate-puberulous
Petal shape	narrow-elliptic to narrow-oblanceolate	narrow-elliptic	narrow-elliptic	narrow-elliptic
Bracteoles	2 or 3 decussate pairs, narrowly ovate, 0.5 mm long	1 pair, minute	1 pair, narrowly triangular, 0.4–0.7 mm long	1 pair, minute
Ovary	sub-globose; stellate-puberulous	obovoid to sub-globose; stellate-puberulous or rarely glabrous	rostrate; glabrous, pilose or rarely villous	narrow-ovoid to rostrate, pilose or rarely villous
Carpels	rounded with blunt knob-like process	rounded	prominently beaked	narrow, elongated
Cocci	3–4 mm long, bullate-verrucose, obtuse conical process 1–2 mm long	to 3 mm long, smooth, shortly apiculate with process <1 mm long	3.5–4 mm long, process 3–4 mm long	3–4 mm long, process 3–4 mm long
Seed	minutely tuberculate, raphe obliquely suspended	smooth, raphe appressed to testa	smooth or with obscure, low tubercles, raphe appressed to testa	not seen
Habitat	sphagnum bog in montane freshwater wetland	margin of watercourses and valleys in open forest, sometimes alpine ridgetops	dry ridgetop in heath and open forest	cliff-top heath

Habitat and Ecology: *Leionema paulii* is restricted to a biogeographically unique, subalpine upland swamp system in an area of impeded drainage at *c.* 930 m elevation. It grows in sphagnum mounds of a bog on the immediate edge of a shallow basin which typically retains high levels of surface water and is underlain with a deep peat layer (Ferguson 2012). Associated vegetation is a mix of predominantly swampland heath with occasional subalpine woodland eucalypts, with abundant *Baeckea utilis*, *Hakea microcarpa*, *Epacris paludosa* and *Empodisma minus*, and *Eucalyptus pauciflora*, *Acacia melanoxylon* and *Tasmannia lanceolata* scattered throughout. This community falls within the montane bog and fen formation of the freshwater wetland vegetation class (Keith 2004) and the population is within the plant community type (PCT) Southeast Subalpine Bog (PCT 3948; DPE 2022a). It is also included within the 'Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps bioregions' Threatened Ecological Community listed on the New South Wales *Biodiversity Conservation Act 2016* (DPIE 2017).

Leionema paulii has been seen to reshoot vigorously from the base following drought, though the species is likely to be fire sensitive as in other *Leionema* which recruit from seed following fire and require fire and smoke to germinate (Auld 2001). Pollinators have not been observed on *L. paulii,* but the species is most likely to be primarily insect pollinated as in other species in the genus (Armstrong 1979).

Phenology: The main flowering period has been recorded in late October but is likely to be at least from September to November given the presence of both spent and fresh flowers and flower buds on the type specimen, with other sporadic flowering events recorded in January and February. Ripe fruit with seed dispersing has been observed in late December.

Conservation Status: The sole confirmed population of *Leionema paulii* has been documented by the author as having *c.* 50–60 mature individuals and appears to be highly localised, only occupying an area of *c.* 1500 m^2. Limited searches were conducted in the surrounding swamps between 2016 and 2021 with no other plants seen, with the known habitat seemingly similarly restricted. The author has also performed extensive fieldwork around other swamps in the wider region but has not located *L. paulii* or related species in those areas. Other studies have also failed to locate *Leionema* species in sphagnum in similar habitat across New South Wales (Whinam and Chilcott 2002). An examination of relevant herbarium collections did not uncover any other specimens from other locations attributable to *L. paulii*. However, photographic evidence from the same swamp system *c.* 1 km south of the type locality (currently attributed to *L. phylicifolium*) may prove to be *L. paulii* also (Wood 2022; Atlas of Living Australia 2024). The subalpine bog habitat of *L. paulii*, is known to have a species composition unlike other true alpine bogs and upland swamps in the region (Ferguson 2012). Therefore, there is a likelihood that if other populations do exist, they are also likely to be highly localised.

Threats to the known population include desiccation of the swamp through drought (with death of *c.* 10–20% of mature individuals from those observed in 2019 and 2020) and habitat degradation by feral animals, including pigs and deer. Other potential threats include changes in hydrology, especially increased drying of the wetlands due to climate change, and adverse fire regimes including higher frequency and/or severity fires that can impede recruitment. Given the highly restricted extent of occurrence and area of occupancy, a single threat-defined location when considering the most serious threats of drought and pest animals, observations of continuing decline in mature individuals following the 2017–2019 drought, and habitat decline due to feral animal disturbance, *L. paulii* meets the criteria to be listed as Critically Endangered under Criteria B and C of IUCN (2022), Clause 4.3 and 4.4 of the New South Wales *Biodiversity Conservation Act 2016,* and Criterion 2 and 3 of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

Etymology: The epithet commemorates Paul Ronald Phillips (1956–2012), the father of the author who did much to promote a love of the outdoors and exploration of natural environments from a young age in the tablelands of NSW and beyond, and whose final words included those of encouragement to finish studies in Conservation and Land Management, leading to such discoveries as *Leionema paulii*.

Notes: *Leionema paulii* is morphologically distinct from all populations of *L. phylicifolium*, particularly due to the verrucose leaf surfaces, the 2 or 3 pairs of bracteoles on the flower pedicels, and the bullate-verrucose cocci. In some herbarium specimens of *L. phylicifolium*, the oil glands in the leaves appear to be raised giving a slightly verrucose appearance, but this is an artefact of the drying process. In such specimens, the glands are clearly smaller in size and less prominent than in *L. paulii*, allowing positive identification from vegetative material alone. However, future collections of fertile material will aid identification in some populations of *L. phylicifolium*, especially if further variation is found in new populations. In fresh material, however, the leaf surfaces of *L. paulii* are very distinctly glandular-verrucose when compared to any *L. phylicifolium* observed during field surveys, so field identification is straightforward. The bullate-verrucose surface of the fruit is also reliable when compared to fruiting specimens of *L. phylicifolium* from across its range where such material is available for identification (Fig 3).

Despite the collection of the type specimen from South East Forest National Park in 2019, this is clearly not the first time *L. paulii* has been recorded at the site. Observational records attributed to *L. phylicifolium*, but almost certainly representing *L. paulii*, have been made at the type location during scientific research (Whinam and Chilcott 2002) and floristic surveys (DPE 2022b), but no voucher specimens had been lodged from these projects. Photographic evidence from the site also exists in an identification guide, with plants labelled as *L. phylicifolium*, but matching *L. paulii* due to the distinct glandular-verrucose foliage (Wood 2022). Voucher collections at these times may have facilitated earlier diagnosis and description of *L. paulii,* given some diagnostic details such as the 2–3 pairs of bracteoles, and fruit and seed morphology, are more readily elicited from plant specimens. The collection of voucher specimens of seemingly common taxa, especially on the edges of their ranges, can therefore be of great value in taxonomic studies. Many populations are still under-represented or not represented at all in herbaria, and new populations and range extensions are constantly being found in *Leionema* and many other taxa (Bell 2020). Indeed, the variation within *L. phylicifolium* as identified by Wilson (1970) and Walsh (2004) warrants further investigation in this regard, as do other disjunct populations in the genus (e.g., those found in *L. dentatum* (Sm.) Paul G.Wilson and *L. diosmium* (A.Juss.) Paul G.Wilson; Wilson 1970).

Given the distinct seed and fruit features here noted in *Leionema paulii*, morphology of these characters is a potential avenue of investigation between other populations of *Leionema*, with seed characters highlighted by Wilson (1970, 1998) as being highly diagnostic between genera in Rutaceae tribe Boronieae. In diagnosing genera within this tribe, seed morphology was pointed out to be distinct and uniform within groups (Wilson 1998), and so the discovery of distinctive seed characters in *L. paulii* here (notably the minutely tuberculate testa) and in *L. ceratogynum* previously (low obscure tubercules, Walsh 2004), mean these characters may be useful in diagnosing other taxa within *Leionema* (Fig. 3B). However, these fine details can only be studied under magnification using specimens with ripe fruit, and such fruiting specimens are currently poorly represented in herbaria. Thus, additional collection of fruiting specimens from as many populations as possible is required to further these investigations.

Therefore, an opportunity is identified to engage with those undertaking ecological research and floristic surveys to enable the gathering of further specimen voucher collections in genera of interest given the current acceleration in survey effort across the state, especially related to the development industry (Bell 2020). The legislative requirements for such surveys may represent great opportunities to increase knowledge of biodiversity. As *L. paulii* and other examples (e.g., *Hibbertia fumana* Sieber ex Toelken, Duretto *et al.* 2017; *Homoranthus croftianus* J.T.Hunter, Hunter 1998) demonstrate, early recognition enables planning actions for species of conservation concern to commence sooner. While there remain hurdles to the standardisation of collection of voucher specimens by those undertaking floristic surveys and ecological research, increased knowledge sharing between consultants, researchers and herbaria could result in elevated collection efforts (Bell 2020) and drive further new species discoveries. Indeed, such surveys already typically collect site data detailed enough for herbarium purposes, so the addition of voucher specimens to a workflow is not overly imposing and should be encouraged. Systematic surveys are thus fertile ground for rapidly expanding material available for taxonomic research, as well as engaging more botanists and ecologists in taxonomy. This process may also forge stronger relationships between these fields and help to reveal more about our plant diversity than herbaria collectors alone can manage. Furthermore, the information lodged with the specimens and made available becomes part of the invaluable resources available to the wider community, further promoting flora conservation and the important role taxonomy plays within it.

Key to the species of *Leionema* of NSW and south-eastern Queensland, modified from Alvarez and Duretto (2019) and Telford and Bruhl (2020).

1 Petals >7 mm long, erect or spreading; stamens considerably exceeding petals .....
1: Petals <6 mm long, ± spreading; stamens ±equal to or slightly longer than petals 6
2 Petals fused ..... ***L. sympetalum***
2: Petals free 3
3 Stems ± terete 4
3: Stems strongly angled 5
4 Stems pilose; leaves *c*. 10 mm long ..... ***L. carruthersii***
4: Stems stellate-tomentose; leaves 20–40 mm long ..... ***L. viridiflorum***
5 Leaf margins entire; inflorescence pendulous ..... ***L. ralstonii***
5: Leaf margins frequently serrulate; inflorescence erect ..... ***L. scopulinum***
6 Leaves 2.5–4 cm wide, base stem-clasping ..... ***L. ambiens***
6: Leaves <2 cm wide, base not stem-clasping 7
7 Leaves hairy (including minutely papillose) on abaxial surface 8
7: Leaves glabrous on abaxial surface 14
8 Inflorescence terminal 9
8: Inflorescence axillary 10
9: Petals yellow, pale red towards apex on abaxial surface; leaves pilose or coarsely stellate on lower surface; pedicels 1–2 mm long ..... ***L. diosmium***
9: Petals white; leaves pilose on lower surface; pedicels 3–5.5 mm long ..... ***L. westonii***
10 Leaves 2–8 cm long, apex 2-toothed, margins entire to finely toothed; inflorescences >10 mm long, 1–3-flowered ..... ***L. dentatum***
10: Leaves 0.8–2(–3) cm long, apex entire, margins entire; inflorescences usually <10 mm long, 1–3-flowered 11
11 Ovary subglobose, white stellate-pubescent or rarely glabrous; cocci up to 4 mm long 12
11: Ovary rostrate, glabrous, pilose with few simple hairs or rarely villous; cocci 6 mm long or more 13
12 Leaves smooth on adaxial and abaxial surface; 1 pair of bracteoles; cocci smooth ..... ***L. phylicifolium***
12: Leaves prominently glandular-verrucose on adaxial and abaxial surface; 2–3 pairs of bracteoles; cocci bullate-verrucose ..... ***L. paulii***
13 Inflorescences 3-flowered, rarely some (never all) 1-flowered; leaves straight, mostly 12–21 mm long, abaxial surface visible ..... ***L. ceratogynum***
13: Inflorescences 1-flowered; leaves slightly up-curved, mostly 7–15 mm long, abaxial surface mostly obscured by revolute margins ..... ***L. lachnaeoides***
14 Stems strongly angled, glabrous; leaves 3–7 cm long, narrow-elliptic to oblanceolate, margins finely and regularly toothed, apex acute 15
14: Stems terete to slightly angled, glabrous or hairy; leaves 0.6–5 cm long, margins usually entire or sometimes minutely erose or crenate 16
15 Leaves 50–70 mm long, 10–15 mm wide ..... ***L. coxii***
15: Leaves 25–50 mm long, 3–6 mm wide ..... ***L. obtusifolium***
16 Inflorescences axillary; leaves linear to narrow-oblong or narrow-elliptic, Margins recurved to revolute 17
16: Inflorescences terminal and often also axillary; leaves linear- to broad-spathulate or ± circular, obovate or elliptic, margins flat to recurved 18
17 Flowers solitary; stems pilose ..... ***L. gracile***
17: Inflorescence mostly a cluster of 3 or 4 flowers; stems with stellate hairs ..... ***L. phylicifolium***
18 Leaves >13 mm long 19
18: Leaves <13 mm long 21
19 Leaves 3–11.5 mm wide ..... ***L. beckleri***
19: Leaves 2–3(–4) mm wide 20
20: Stems densely hairy; leaf apex obtuse–rounded ..... ***L. elatius***
20: Stems sparsely hairy; leaf apex acute ..... ***L. praetermissum***
21 Stems pilose ..... ***L. gracile***
21: Stems with stellate hairs 21
22 Stems verrucose; leaves 2–4 mm wide ..... ***L. lamprophyllum***
22: Stems not verrucose; leaves 4–6 mm wide 23
23 Leaves distally crenulated; apex of midrib with a tuft of stellate hair ..... ***L. beckleri***
23: Leaves distally rounded; apex of midrib glabrous ..... ***L. rotundifolium***

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References

Alvarez PR, Duretto MF (2019) *Leionema praetermissum* (Rutaceae), a new restricted endemic for New South Wales. *Telopea* 22: 67–73. DOI

Anderson FM (1999) New subspecies of *Leionema lamprophyllum* (F.Muell.) Paul G. Wilson (Rutaceae). *Muelleria* 12: 227–234. URL

Armstrong JA (1979) Biotic pollination mechanisms in the Australian flora – a review. *New Zealand Journal of Botany* 17: 467–508. DOI

Atlas of Living Australia (2024) Occurrence record: NatureMapr – 40511. URL (accessed 2 January 2024)

Auld TD (2001) The ecology of the Rutaceae in the Sydney region of south-eastern Australia: Poorly known ecology of a neglected family. *Cunninghamia* 7: 213–239.

AVH (Australian Virtual Herbarium) (2024) Images from occurrence records for *Leionema phylicifolium* held at the National Herbarium of Victoria. URL (accessed 2 January 2024).

Bell SAJ, Walsh NG (2015) *Leionema lamprophyllum* subsp. *fractum* (Rutaceae); a new and highly restricted taxon from the Hunter Valley of New South Wales. *Telopea* 18: 505–512. DOI

Bell SAJ (2020) Voucher specimens vs observation records: why 'collecting' is better than 'observing' for plant conservation. *Australian Plant Conservation* 29(2): 3–7.

Copeland LM, Telford IRH (2018) *Leionema westonii* (Rutaceae), a rare new species from north-eastern New South Wales, Australia. *Telopea* 21: 19–24. DOI

DAWE (Department of Agriculture, Water and Environment) (2012) Interim Biogeographic Regionalisation for Australia, Version 7. URL (accessed 10 December 2022).

DPE (Department of Planning and Environment) (2022a) *NSW State Vegetation Type Map C1.1M1*. Source: SEED, exported 6 December 2022.

DPE (Department of Planning and Environment) (2022b) Records of Mountain Phebalium (Species: *Leionema phylicifolium*) [dataset]. Source: NSW BioNet Atlas, exported 6 December 2022.

DPIE (Department of Planning, Industry and Environment) (2017) Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps bioregions – profile. URL (accessed Feb 2020).

Duretto MF, Durham KL, James EA, Ladiges PY (2006) New subspecies of *Leionema bilobum* (Rutaceae). *Muelleria* 23: 7–14. DOI

Duretto MF, Orme AE, Rodd J, Stables M, Toelken H (2017) *Hibbertia fumana* (Dilleniaceae), a species presumed to be extinct rediscovered in the Sydney region, Australia. *Telopea* 20: 143–146. DOI

Environmental Systems Research Institute (ESRI) (2015). ArcGIS 10.4 for desktop. Redlands, California, USA. Esri Inc. 1999–2005.

Ferguson S (2012) Wetlands Australia National Wetlands Update 2012. URL

Forster PI (2003) *Phebalium distans* P.I.Forst (Rutaceae), a new and endangered species from south-eastern Queensland, and reinstatement of *P. longifolium* S.T.Blake. *Austrobaileya* 6: 437–444. URL

Forster PI (2005) New species in *Philotheca* Rudge (Rutaceae) from Queensland. *Austrobaileya* 7: 175–181. URL

Hunter JT (1998) Two new rare species of *Homoranthus* (Myrtaceae: Chamelaucieae) from the Northern Tablelands of New South Wales. *Telopea* 8: 35–40. DOI

IUCN Standards and Petitions Subcommittee (2022) Guidelines for Using the IUCN Red List Categories and Criteria. Version 15.1 (July 2022). Standards and Petitions Committee of the IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK.

Keith DA (2004) *Ocean Shores to Desert Dunes: The Native Vegetation of New South Wales and the ACT*. (Department of Environment and Conservation, Hurstville, Australia).

Orel HK, Brigg JD, Duretto MF (2023) *Zieria nubicola* (Rutaceae), a new and highly restricted species from New South Wales, Australia. *Telopea* 26: 169–174. DOI

Telford IRH, Bruhl JJ (2020) Morphological data indicate the subspecies of *Leionema elatius* (Rutaceae) are not conspecific and both should be treated as species. *Telopea* 23: 197–203. DOI

Walsh NG (2004) A new species of *Leionema* (Rutaceae) from south-eastern New South Wales. *Telopea* 10: 805–810. URL

Whinam J, Chilcott N (2002) Floristic description and environmental relationships of *Sphagnum* communities in NSW and the ACT and their conservation management. *Cunninghamia* 7: 463–500.

Wilson PG (1970) A taxonomic revision of the genera *Crowea, Eriostemon* and *Phebalium* (Rutaceae). *Nuytsia* 1: 3–155. DOI

Wilson PG (1998) New species and nomenclatural changes in *Phebalium* and related genera (Rutaceae). *Nuytsia* 12: 267–288. DOI

Wilson PG (2013) *Leionema* (Rutaceae). In: *Flora of Australia* 26: 431–446.

Wood B (2022) *Leionema phylicifolium* in 'Plants of South Eastern New South Wales'. URL (accessed 6 December 2022).

BOTANIC GARDENS OF SYDNEY

Telopea

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A new species of *Olearia* (Asteraceae: Astereae) from the Australian Capital Territory and adjacent New South Wales

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Abstract

Olearia heloderma Albr. & I.Telford*, sp. nov.*, a distinctive species from the mountainous region near the Australian Capital Territory and New South Wales border is described and illustrated, with notes on distribution, habitat, conservation status, relationships and features distinguishing it from other species of *Olearia*.

Introduction

As currently circumscribed, *Olearia* Moench is the largest genus of tribe Astereae in Australia with ca. 113 species (Schmidt-Lebuhn 2022). Molecular phylogenies have demonstrated its non-monophyly (Cross et al. 2002). Recent work on Astereae in New Zealand centred on *Celmisia* Cass. and relatives has confirmed that the species of *Olearia* are divided into two distantly related clades. The first clade is subtribe Brachyscominae Nesom, a predominantly Australian lineage including ca. 90 species of *Olearia*, the genera *Brachyscome* Cass., *Calotis* R.Br., *Vittadinia* A.Rich., *Minuria* DC., and many smaller genera; the second clade is subtribe Celmisiinae Saldivia comprising *Celmisia*, the remainder of *Olearia*, and a few small island genera (Nesom 2020a; Saldivia & Nicol 2023).

Nesom (2020b) proposed to split ten new genera from the Australian lineage of *Olearia*, several of them to accommodate only one or two species. However, this proposed taxonomy has not yet found broad acceptance. In support of the suggested genera, Nesom cited the results of Cross et al. (2002). Although a major advance at the time, these results were based on only a single sequence region, and sampling of fewer than half the species of *Olearia* and a few species from related genera. Those results also provided little topological resolution to support this level of taxonomic change, with much of the tree forming two large polytomies.

In 1975, amateur botanist Margaret Parris discovered a distinctive species of *Olearia* (*sens.lat.*) in the mountainous region near the Australian Capital Territory and New South Wales border. Further searches by Ian Telford and colleagues in 1980s and 1990s uncovered additional populations in the vicinity. A manuscript name, *Olearia rhizomatica*, was published as a *nomen nudum* by Lander (1992) who was revising *Olearia*. The Australian Plant Census (Council of Heads of Australasian Herbaria 2011) adopted the phrase name *Olearia* sp. Rhizomatica (I.R.Telford 11549) based on Lander's manuscript name, but the species has remained without a formally published name despite being recognised as distinct for over 40 years.

Albrecht DE et al. (2024) A new species of *Olearia* (Asteraceae: Astereae) from the Australian Capital Territory and adjacent New South Wales. *Telopea* 27: 23–28. doi:10.7751/telopea17735

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All Populations of *Olearia* sp. Rhizomatica in the ACT were burnt by the 2019–2020 'Black Summer' bushfires, and many in NSW https://www.bushfirefacts.org/fire-maps.html. Based on the potential post-fire impacts of herbivory, *Olearia* sp. Rhizomatica was identified as one of 486 plant species having a high priority for urgent management intervention to support recovery from the 2019–2020 bushfires (see https://www.dcceew.gov.au/environment/biodiversity/bushfire-recovery/bushfire-impacts/priority-plants).

The Bushfire Recovery project 'Survive and Thrive', which currently has an Australian Capital Territory-focus, was borne out the need to develop *ex-situ* vegetative and seed stocks as insurance against extinction in the wild due the impact of wildfire or climate change. Of the twelve species from the Australian Alps bioregion identified as having a high priority for urgent management intervention, *Olearia* sp. Rhizomatica was selected as one of five species to be initially targeted for the 'Survive and Thrive' project (https://parkstrust.org.au/survive-and-thrive/). The increased focus on *Olearia* sp. Rhizomatica has provided impetus to formally publish this species.

Methods

Preserved specimens housed at the Australian National Herbarium (CANB, including CBG) and live, cultivated material grown under favourable conditions at the Australian National Botanic Gardens (ANBG) were examined when preparing the species description. Capitula on pressed specimens were rehydrated with boiling water prior to assessing floral characters. Capitula length was measured from the base of involucre to tip of the corolla lobes of the disc florets. Involucre diameter was measured at anthesis. Anther length includes the terminal appendages.

Cultivated material of underground structures that give rise to shoots was fixed in 70% ethanol. Hand-cut transverse sections were made with a single-sided razor blade in distilled water, transferred to 0.5% toluidine blue O (Feder & O'Brien 1968) for ca. 20 s, washed twice in distilled water and mounted on a microscope slide in distilled water, covered with a glass slip, and examined under bright field using a Nikon Eclipse 90i motorised compound microscope and Nikon DSRI1 Colour Digital Camera.

Nearly all Australian species of Asteraceae tribe Astereae, including *Olearia* sp. Rhizomatica, were sequenced for Angiosperms 353 target capture data (Johnson et al. 2019). The phylogeny is being prepared for publication (Stephanie Chen et al., unpubl. data) and discussing it in detail is beyond the scope of this paper, so we restrict ourselves to commenting on the placement of *Olearia* sp. Rhizomatica. Laboratory, bioinformatic, and phylogenetic methods followed Schmidt-Lebuhn & Grealy (2024).

Taxonomy

Olearia heloderma Albr. & I.Telford, ***sp. nov.***

Type: New South Wales: Southern Tablelands: Scabby Range, head of Sams Creek, 3 km S of Mt Kelly, 22 Jan 1982, *I.R.Telford 11541, F.E.Davies, A.M.Lyne & S.York* (holo: CBG 9200477!; iso: AD, BRI, HO, MEL, NSW, PERTH).

Olearia rhizomatica Lander, *nom. inval.*, in G.J.Harden (ed.), *Fl. New South Wales* 3: 195 (1992).

Olearia rhizomatica J.D.Briggs & Leigh, *nom. inval., nom. nud.*, J.D.Briggs & J.H.Leigh, *Rare or Threatened Austral. Pl.* 32 (1996).

Olearia sp. Rhizomatica (I.R.Telford 11549) Australian National Herbarium [Council of Heads of Australasian Herbaria (2011), *Australian Plant Census*].

Ascending to spreading low *shrub* to 40 cm high, sometimes spreading vegetatively by root suckers. *Indumentum* on stems, leaves, peduncles and involucral bracts consisting of flagellate hairs (eglandular simple hairs with a wispy terminal extension) and sometimes also shorter gland-tipped hairs (when present most visible on leaf and involucral bract margins). *Stem* internodes with decurrent longitudinal ribs extending downwards from either side of leaf bases; young branchlets with a moderate to dense indumentum dominated by flagellate hairs, distinctly sparser or absent immediately below leaf attachment. *Leaves* alternate, often crowded, spreading to ascending, sessile, mildly aromatic when crushed, stub-like bases persisting on older stems; lamina shallowly conduplicate, narrowly cuneate to spatulate in outline, (3–)5–16 mm long, (1–)2.0–6.2 mm wide at widest point distally, 0.5–1.4 mm wide at narrowest point proximally, concolorous, green, adaxial surface glabrous or with very sparse gland-tipped hairs and/or flagellate hairs along midvein, abaxial surface glabrous or with gland-tipped and/or flagellate hairs along midvein; texture rather thick when fresh, particularly just in from the margins (hereafter submargins) which are glandular verrucose abaxially, the uneven texture becoming more accentuated when dry with sunken and raised regions including a somewhat keeled midvein abaxially; venation indistinct apart from midvein; base gradually narrowing, though sometimes broadening slightly at attachment; margins flat, with scattered gland-tipped and/or flagellate hairs, a distal tooth or lobe sometimes present on one or both sides of the blade below the 3-lobed apex, rarely with both marginal and apical lobes absent; apical lobes acute to obtuse, muticous or rarely with a tiny acute terminal callus. *Capitula* terminating the main axes and lateral shoots, solitary, pedunculate, radiate, 6.0–8.0 mm long, 18–33 mm diameter. *Peduncles* 15–68 mm long, indumentum dense though underlying tissue partly visible, with a few short antrorse bracts (resembling the outer involucral bracts) along their length. *Involucre* hemispherical, 6.6–12 mm diameter; bracts 35–55, 3–4-seriate, all strongly reflexed after fruit shed; outer involucral bracts subulate, 2.0–5.7 mm long, 0.3–0.7 mm wide, sometimes curving outward in the distal half, green, midvein inconspicuously glandular verrucose, glabrous or with scattered marginal gland-tipped and/or flagellate hairs, margins non-membranous, apex long acute; inner involucral bracts narrowly lanceolate, 2.8–6.0 mm long, 0.6–1.1 mm wide, green, midvein inconspicuously glandular verrucose, glabrous, hyaline scarious margins 0.05–0.2 mm wide, serrulate, apex long acute. *Receptacle* convex, 2.0–4.0 mm across, with short irregular projections between the floret scars. *Ray florets* 20–51, 1–2-seriate, female, corolla tube 2.0–4.0 mm long, with very sparse minute antrorse simple hairs externally, especially near apex, rarely virtually glabrous; ligules 6.5–13.0 mm long, 1.2–2.6 (–3.0) mm wide, violet, apex rounded, shortly 3-lobed, occasionally ray florets producing 1–2 shorter and narrower additional ligules; stylar arms linear, 0.7–1.0 mm long. *Disc*

florets 32–88, bisexual, yellow, corolla tube 3.0–5.2 mm long, with very sparse minute antrorse to spreading simple hairs externally, especially near apex, rarely virtually glabrous; corolla lobes 0.7–1.3 mm long, acute; anthers 1.3–2.0 mm long including narrowly triangular sterile terminal appendages c. 0.4 mm long; stylar arms narrowly oblong to linear–oblanceolate, 0.7–1.0 mm long. *Cypsela* oblong-elliptic to oblong-obovoid, elliptical in cross-section, 1.7–2.3 mm long, 0.6–0.8 mm wide, 0.3–0.5 mm thick, light brown, 6–9–ribbed, with appressed or antrorse white duplex hairs throughout, carpopodium slightly oblique. *Pappus* 2-seriate (outer row of bristles usually incomplete); longer bristles 22–36, 3.2–5.3 mm long, outer row of bristles much shorter, white. (Fig. 1)

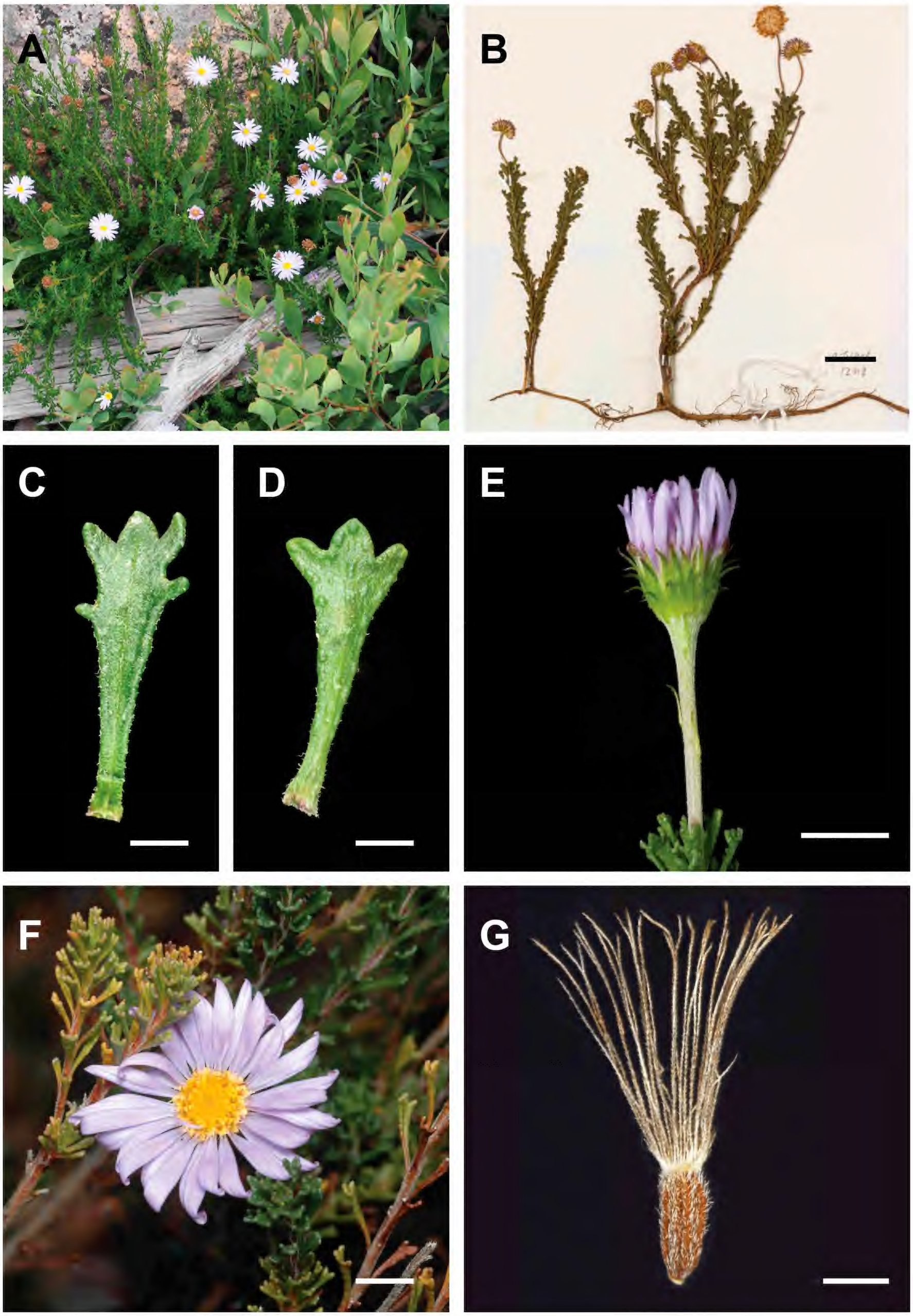

Fig. 1. *Olearia heloderma*: **A,** habit, with broader-leaved *Daviesia mimosoides* at right; **B,** specimen showing root suckering; **C,** detached leaf showing adaxial surface; **D,** detached leaf showing abaxial surface; **E,** capitulum in late bud; **F,** capitulum at anthesis; **G,** cypsela. Scale bars: A = 20 mm; C & D = 2 mm; E & F = 5 mm; G = 1 mm. Images A by A.McLachlan from *T.North 2296*; B by Centre for Australian National Biodiversity Research from *I.R.Telford 12018 & D.J.Mallinson*); C–F by M.Fagg from *I.R.Telford 11541 & F.E.Davies, A.M.Lyne, S.York*; G, by J.FitzGerald from *T.North* 2310.

Diagnostic characters: A distinctive species distinguished from other species of *Olearia* by the following combination of characters: root-suckering low shrub; indumentum densest on stems and peduncles and dominated by flagellate, eglandular hairs; leaves alternate, narrowly cuneate to spatulate, crowded, rather short with distinctive lobing and glandular verrucose submargins; involucral bracts with inconspicuously glandular verrucose midvein; ligules violet, cypsela 1.7–2.3 mm long, 6–9-ribbed and with appressed or antrorse white duplex hairs throughout.

Specimens examined: NEW SOUTH WALES: Southern Tablelands: Scabby Range Nature Reserve, 2.9 km W of Mt Gudgenby, on tributary of Sams Creek, 9 Jan 2003, *I. Crawford 7331* (CANB); Scabby Range, Namadgi National Park, 17 Dec 1987, *P.Gilmour 6328* (CBG); c. 60 km S of Canberra, Yaouk Bill Range, Yaouk Peak. c. 150-200m SE of trig, 9 Jan 1996, *L.Halasz 2* (CANB, NSW, PERTH); Namadgi National Park, Scabby Range, 2.5 km SSW of Mt Kelly, 22 Jan 1992, *I.R.Telford 11542* (CBG); Gurrangorambla Range, Mount Morgan, 12 Jan 1994, *I.R.Telford 12018 & D.J.Mallinson* (CBG, NSW, PERTH). AUSTRALIAN CAPITAL TERRITORY: c. 0.5 km NW of Namadgi Trig, Namadgi National Park, 18 Dec 1987, *P.Gilmour 3353* (CBG); Big Creamy Flat, Namadgi National Park, 3 Feb 1988, *P.Gilmour 6569* (CBG, NSW); Sentry Box, Scabby Range, Namadgi National Park, 17 Jan 2022, *T.North 2296* (CANB); Sentry Box Hill, 3 May 1975, *M.Parris s.n.* (CBG); Sentry Box Hill, 1 km ENE of summit, 14 Jan 1981, *I.R.Telford 8584 & M.Parris* (CBG, NSW, PERTH); Sentry Box Hill, 1 km ENE of summit, 14 Jan 1981, *I.R.Telford 8592 & M.Parris* (CBG); Sentry Box Hill, 1 km ENE of summit, 18 Mar 1981, *I.R.Telford 8626* (CBG); Gudgenby Nature Reserve, c. 1 km SE of Sentry Box Hill, 3 Apr 1984, *I.R.Telford 9668* (CBG); Namadgi National Park, Scabby Range, head of Porcupine Creek, 2.5 km SE of Yaouk Gap, 11 Mar 1992, *I.R.Telford 11549* (CBG, MEL, NSW, PERTH); Namadgi National Park, Scabby Range, Mt Scabby, headwaters of Cotter River, 11 Mar 1992, *I.R.Telford 11555* (CBG, NSW); Namadgi National Park, Scabby Range, ACT-NSW border fence, 2.5 km SE of Yaouk Gap, 11 Mar 1992, *I.R.Telford 11556* (CBG). CULTIVATED: Australia National Botanic Gardens, nursery np1, 11 Nov 2021, *R.Purdie 12895* (CANB).

Distribution: Based on specimens at CANB and CBG, *Olearia heloderma* is currently known from approximately 12 sites dispersed around the border region between the ACT and NSW centred on the Scabby Range Nature Reserve (Fig. 2). Additional populations are likely to be discovered with further targeted survey effort, however much of the area within the species extent of occurrence is time-consuming and challenging to access by foot due to the terrain. Helicopter access is an easier, though more expensive option for facilitating further survey.

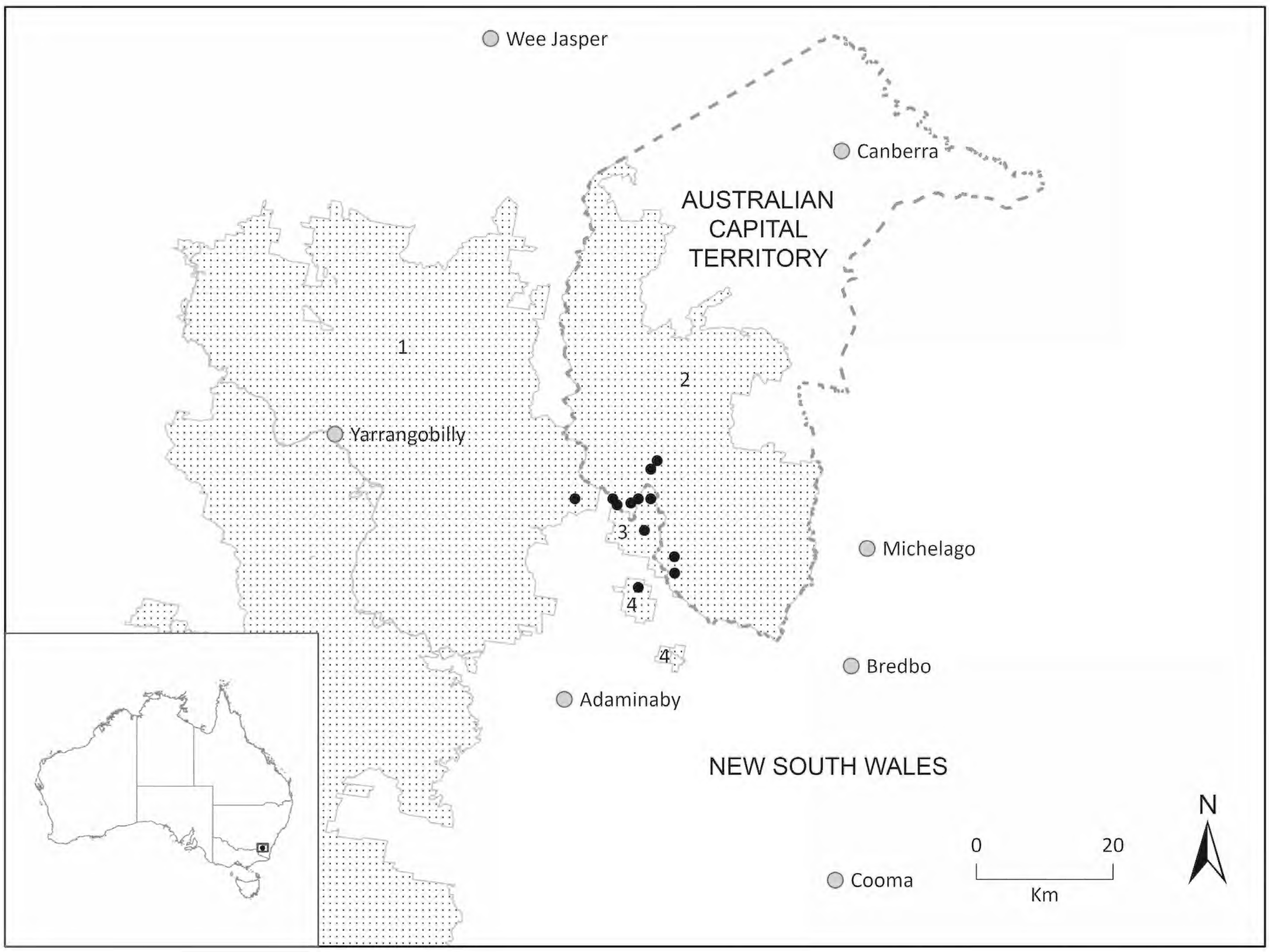

Fig. 2. Distribution of *Olearia heloderma* (solid black circles) based on specimens in Australian herbaria. Conservation reserves shown in stipple: 1 = Kosciuszko National Park, 2 = Namadgi National Park, 3 = Scabby Range Nature Reserve, and 4 = Yaouk Nature Reserve.

Conservation status: All known populations of *Olearia heloderma* occur within conservation reserves. In the ACT it occurs within the Bimberi Wilderness zone of Namadgi National Park. In NSW it occurs within Kosciuszko National Park, Scabby Range Nature Reserve and Yaouk Nature Reserve.

The species is currently not listed as threatened in New South Wales or the Australian Capital Territory, however assessment of its conservation status is hampered by limited knowledge of population sizes and threatening processes. Data associated with herbarium collections indicate that some sites have few plants, whilst it is common at other sites. The species appears to resprout post-fire, however no data are currently available on post-fire seedling recruitment. A limited quantity of seed is currently stored in the ANBG seed bank.

Habitat: *Olearia heloderma* occurs in mountainous granitic terrain at elevations of 1450 to 1800 m. Most occurrences are on gentle to steep slopes of various aspect, but it has also been found on ridge tops. Plants grow in gravelly loam derived from decomposing granite, often amongst outcropping rocks (Fig. 3). Most records are from subalpine vegetation types including *Eucalyptus pauciflora* woodland, shrubland and heathland. There is a solitary record from *Eucalyptus delegatensis*-dominated tall montane open forest. Frequently recorded associated species include *Daviesia* spp., *Eucalyptus pauciflora*, *Kunzea muelleri*, *Leptospermum* spp., *Oxylobium ellipticum*, *Poa* spp., *Podolobium alpestre* and *Veronica perfoliata*.

Fig. 3. Typical habitat of *Olearia heloderma* on Mt Namadgi. Image by E.Cook (no voucher).

Phenology: Flowering specimens have been collected in the field from December to April and fruiting specimens in March and April. As very limited fieldwork has been undertaken in other months, the recorded flowering and fruiting period may be inaccurate. Cultivated plants afforded frost protection have flowered as early as August in the ANBG.

Etymology: The specific epithet is a noun in apposition and derived from the Greek, *helos*- nail, stud or wart (see Brown 1956: 842) and *derma*- skin, in reference to the glandular verrucose leaf submargins, and the resemblance of the leaf submargin texture to the skin of the helodermatid lizard *Heloderma suspectum* Cope, the Gila Monster.

Affinities: *Olearia heloderma* is very distinctive morphologically and unlikely to be confused with any other species of *Olearia sens. lat.*, particularly on account of its short, narrowly cuneate to spatulate leaves with a 3-lobed apex and glandular verrucose submargins.

The evolutionary relationships of *Olearia heloderma* are currently not well resolved except that it is related to the main Australian lineage of *Olearia* as opposed to Celmisiinae (Stephanie Chen et al., unpubl. data). Preliminary phylogenetic analyses using Angiosperms353 target capture data (Johnson et al. 2019) failed to place the species consistently, and sometimes in an isolated position. A possible reason is that relatively limited data were recovered for the sample, with e.g. sequences available for only 91 of the 262 genes that were used in one of the analyses. It can therefore not be said with certainty if *O. heloderma* is part of *Olearia sens. str.* or any of the segregate genera proposed by Nesom (2020b). Because of the absence of firm evidence, and given that the majority of Australian species of *Olearia* in the preliminary analyses formed a large clade including the type species of the genus, we have chosen to describe *O. heloderma* under *Olearia*. Future work should aim to test the phylogenetic relationships of this species, and this may warrant a subsequent transfer to a different genus.

Notes: Initially, it appeared that upright shoots produced away/remote from the parent plant were rhizomes, hence the epithet as originally proposed by Lander, and subsequently adopted as part of the phrase name. Our investigations (Fig. 4) have shown that the underground more-or-less horizontal structures are roots and the vertical growths from them 'root suckers'. The anatomy of these structures in transverse section (Fig. 4B) is typical of eudicot roots without central pith, with central xylem, the vascular tissue surrounded by cortex, and the formation of lateral roots initiated to the outside of the vascular cylinder (cf. Raven et al. 1999).

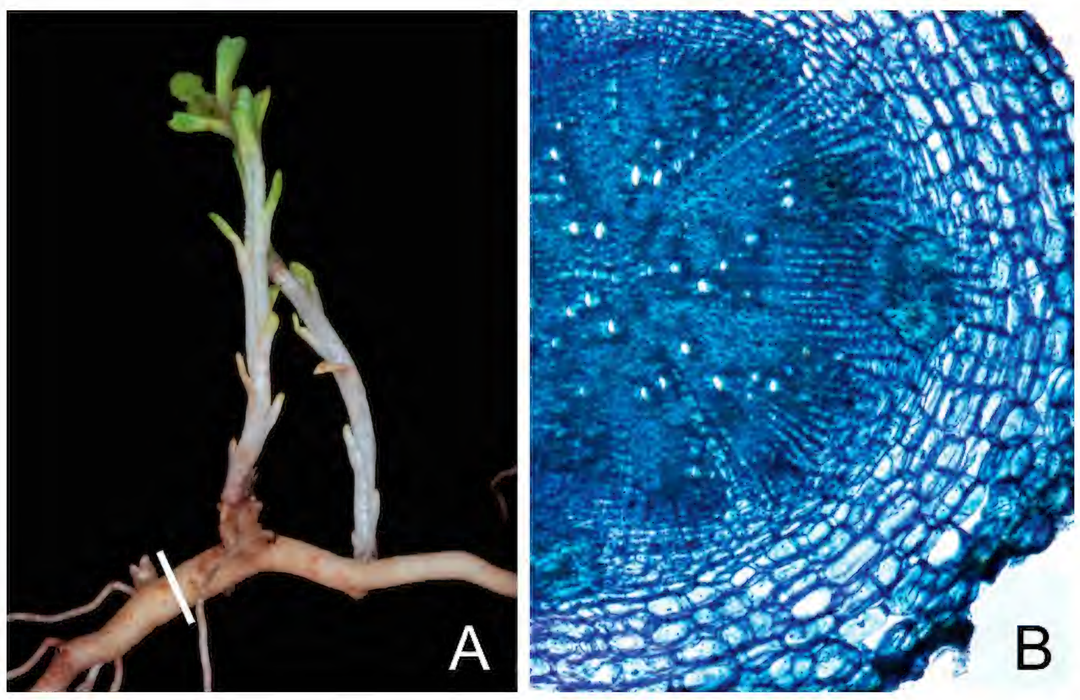

Fig. 4. Underground structures in *Olearia heloderma*: **A.** root with several thin lateral roots and two stem shoots visible. White line indicates location of transverse section; **B.** transverse section of root stained with Toluidine Blue O with primordial lateral roots developing (staining lighter blue) at 3 and 6 o'clock. Scale: A, Root diameter at white line = 1.2 mm; B, Root radius 0.6 mm. Images by J.J. Bruhl from *R.Purdie 12895* (CANB).

The multicellular, flagellate, eglandular hairs found on stems, leaves, peduncles and involucral bracts frequently break off but may retain a persistent base. These persistent hair bases could be confused with short gland-tipped hairs, which are sometimes present and most visible on the leaf and involucral bract margins.

Olearia heloderma (as *Olearia* sp. Rhizomatica) is included in the key to New South Wales species of *Olearia* (PlantNET 2023), however, to arrive at *O. heloderma* a user would have to follow the 'leaves viscid on upper surface' lead in one of the key couplets. This requires correction, because although the leaves have glands embedded in the leaf tissue there is no evidence of the upper surface being viscid.

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References

Brown RW (1956) 'Composition of Scientific Words.' (Smithsonian Institution Press: Washington and London).

Council of Heads of Australasian Herbaria (2011) *Australian Plant Census*. URL (Accessed 19 September 2022)

Cross EW, Quinn CJ, Wagstaff SJ (2002) Molecular evidence for the polyphyly of *Olearia* (Astereae: Asteraceae). *Plant Systematics and Evolution* 235: 99–120. DOI

Feder N, O'Brien TP (1968) Plant microtechnique: some principles and new methods. *American Journal of Botany* 55: 123–42. DOI

Johnson MG, Pokorny L, Dodsworth S, Botigué LR, Cowan RS, Devault A, Eiserhardt WL, Epitawalage N, Forest F, Kim JT, Leebens-Mack JH, Leitch IJ, Maurin O, Soltis DE, Soltis PS, Wong GK, Baker WJ, Wickett NJ (2019) A universal probe set for targeted sequencing of 353 nuclear genes from any flowering plant designed using k-medoids clustering. *Systematic Biology* 68: 594–606. DOI

Lander NS (1992) *Olearia*. In GJ Harden (ed.) 'Flora of New South Wales' vol. 3: 185–197 (New South Wales University Press: Kensington).

Nesom GL (2020a) Revised subtribal classification of Astereae (Asteraceae). *Phytoneuron* 2020-53: 1–39. PDF

Nesom GL (2020b) New genera from Australian *Olearia* (Asteraceae: Astereae). *Phytoneuron* 2020-65: 1–94. PDF

PlantNET (2023) *The NSW Plant Information Network System*. Royal Botanic Gardens and Domain Trust, Sydney. URL (Accessed 26 September 2023)

Raven PH, Evert RF, Eichhorn SE (1999) 'Biology of Plants.' 6th ed. (W.H.Freeman: New York).

Saldivia P, Nicol DA (2023) An overview of Celmisiinae (Astereae): a diverse endemic Australasian lineage. *Capitulum* 3: 1–25. DOI

Schmidt-Lebuhn A (2022) Daisies Down Under: Review of the state of taxonomy and phylogenetics of native Australian Asteraceae. *Capitulum* 1: 33–52. DOI

Schmidt-Lebuhn AN, Grealy A (2024) Transfer of *Cotula alpina* to the genus *Leptinella* (Asteraceae: Anthemideae). *Australian Systematic Botany* 37: SB23012. DOI

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A new species of *Vallisneria* L. for Western Australia and recircumscription of *V. triptera* S.W.L.Jacobs & K.A.Frank

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Abstract

Vallisneria kristinae R.W.Jobson & Dunning (Hydrocharitaceae) is described as a new species endemic to North Kimberley, Western Australia. It was previously included within the Northern Territory species *V. triptera* S.W.L.Jacobs & K.A.Frank. Here it is distinguished from that species based on its overall smaller size and weakly-winged fruit capsules. We also find strong genetic differentiation with accessions sampled from across the entire distribution of both taxa. We present a phylogeny based on nuclear ITS and plastid *trnK 5′* intron data that also includes all Australian species of *Vallisneria*. Along with a redescription of *V. triptera s. str.*, diagnostic features are illustrated, a taxonomic key containing all Australian species is provided, and distribution, habitat, and conservation status are discussed.

Introduction

Worldwide there are 17 recognised species of *Vallisneria* P.Micheli ex L. (Shen 2000, 2001; Les et al. 2008; Martin & Mort 2023), with Australia having the greatest diversity with eight species (Jacobs & McColl 2011, 2023). A major vegetative character distinguishing groups within the genus involves growth form, with three facultative annual species sharing a caulescent vegetative growth form, while the remainder are annuals or perennials sharing a basally rosulate vegetative growth form (Les et al. 2008; Jacobs & McColl 2011). Following the molecular phylogenetic results of Les et al. (2008), *Maidenia rubra* Rendle was included under *Vallisneria*, with close phylogenetic affinity shown to *V. triptera*. All three of the cauline species *V. rubra* (Rendle) Les & S.W.L.Jacobs, *V. triptera* S.W.L.Jacobs & K.A.Frank and *V. caulescens* Bailey & F.Muell. are northern Australian endemics, with *V. triptera* restricted to a few creeks near Jabiru, NT (the vicinity of the type collection) and disjunct populations in northern Kimberley region of Western Australia (Jacobs & McColl 2011). *Vallisneria triptera* and *V. rubra* differ from *V. caulescens* in having female flowers being tripartite instead of bipartite (McConchie 1983; Jacobs & Frank 1987; McConchie & Kadereit 1987). The fruit of *V. triptera* differs from *V. caulescens* in being tripartite vs. bipartite, while that of *V. rubra* is cylindrical (rarely tripartite) and not winged (Jacobs & McColl 2011).

Les et al. (2008) found all three caulescent species to be monophyletic but with weak support (BS = 32; BB = 0.18) using combined nuclear ribosomal (nrDNA) ITS and plastid gene regions *rbcL* and *trnK 5′* intron. Martin and Mort (2023) added 18 accessions to this dataset and found the African/Eurasian species *V. spiralis* L. and *V. denseserrulata*

Richard W. Jobson & Luke T. Dunning (2024) A new species of *Vallisneria* L. for Western Australia and recircumscription of *V. triptera* S.W.L.Jacobs & K.A.Frank. *Telopea* 27: 29–40. doi:10.7751/telopea17993

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(Makino) Makino sister to a supported clade (BS = 99; BB = 1.0) containing two accessions of *V. caulescens* which in turn was sister to all other species, including *V. rubra* and *V. triptera* that were supported (BS = 86; BB = 1.0) as sister species. From that study Martin & Mort (2023) described the new rosulate species *V. jacobsii* A.P.Martin & D.N.Wilson which was supported (BS = 80; BB = 1.0) as sister species to three accessions of *V. australis* S.W.L.Jacobs & Les, and distinguished morphologically from that species based on leaf colour and the former species' apparent distichous growth form at the base of rosettes.

In the current study, we increased the molecular sampling of Martin & Mort (2023), particularly a geographically-dispersed sampling of the three caulescent species, including the first sequenced samples of *V. triptera* populations from the northern Kimberley. From an analysis of molecular data and an examination of morphology we here differentiate the NT populations of *V. triptera* from those of the northern Kimberley region, describing the latter as a new species *V. kristinae* R.W.Jobson & Dunning. Comparisons with closely related *Vallisneria triptera* accessions from across the Northern Territory distribution are provided. Diagnostic features are illustrated, and distribution, habitat, and conservation status are discussed. We also include a modified key to the *Vallisneria* species of Australia (expanding Jacobs and McColl 2011).

Methods and materials

Taxon sampling

Relevant dried and alcohol-preserved material representing all related species, held at the National Herbarium of New South Wales (NSW), Queensland Herbarium (BRI), Australian National Herbarium (CANB), Northern Territory Herbarium (DNA), and Western Australia Herbarium (PERTH), were examined. The description of *V. triptera* used in this text is a modification of that included in Jacobs & McColl (2011) with new measurements of fruit and leaves obtained from the holotype and additional Jabiru specimens held at NSW, excluding previously included data from Kimberley specimens. Two samples of *Nechamandra alternifolia* (Roxb. ex Wight) Thwaites were selected as outgroups for *Vallisneria* based on Les et al. (2008): nuDNA ITS (GenBank: AY870381, EF143023) and plastid *trnK* 5′ intron marker (GenBank: AY335967, EF142957). GenBank numbers of all previously published ingroup accessions can be found in the tables of Les et al. (2008) and Martin and Mort (2023). The final dataset contained 93 ingroup accessions of which 26 were previously unpublished (Table 1). DNA isolation was performed as for Jobson et al. (2017). Location details of newly published ingroup accessions relevant to this study were used to create a distribution map (Fig. 1).

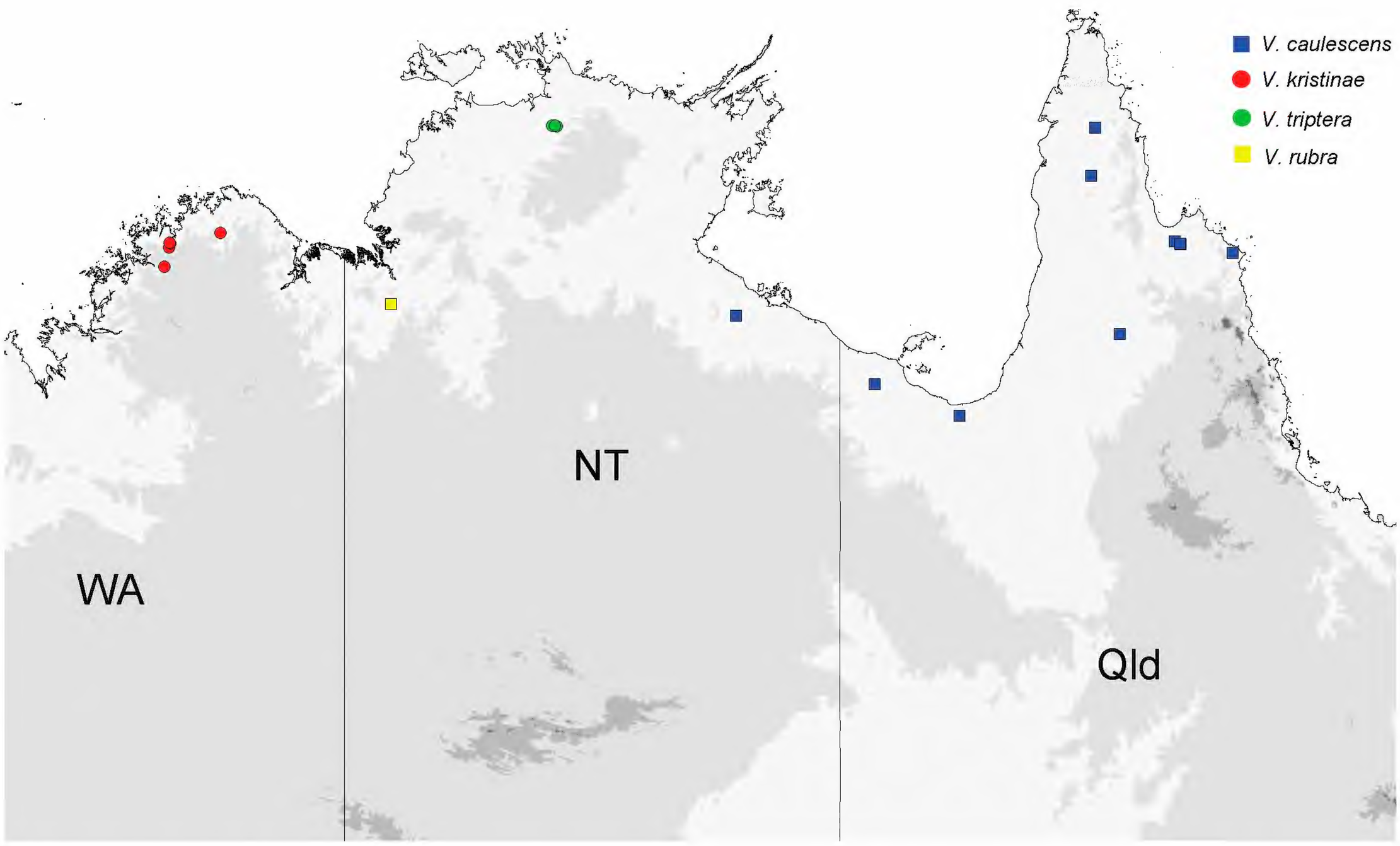

Fig. 1. Distribution map showing accessions of species with cauline leaf arrangement used in the molecular phylogeny of *Vallisneria*. *V. kristinae* (red circle), *V. triptera* (green circles), *V. rubra* (yellow square), *V. caulescens* (blue squares). Accession details shown in Table 1.

Table 1. Previously unpublished accessions used in the nrDNA ITS and cpDNA *trnK 5′* matrices. Secondary collectors are not included. Locality abbreviations: NT: Northern Territory; Qld: Queensland; WA: Western Australia. GenBank accession numbers for sequences are shown. N.A. indicates sequencing failed or was not carried out.

Lab #	Taxon	Collector	Coll. Date	Location	ITS	matK
V22	*V. australis* S.W.L.Jacobs & Les	Keighery, G.J. 5905 (CANB)	23/02/1983	Margaret River Bridge, Margaret River, WA	OR936254	N.A.
V05	*V. caulescens* F.M.Bailey & F.Muell.	Hellquist, B. 8204 (NSW)	3/08/1997	Hann River Crossing, Cook, Qld	OR936240	N.A.
V06	*V. caulescens* F.M.Bailey & F.Muell.	Jacobs, S.W.L. 8232 (NSW)	10/08/1997	WNW of Rokeby Ranger Station, Cook, Qld	OR936241	N.A.
V08	*V. caulescens* F.M.Bailey & F.Muell.	Jacobs, S.W.L. 1360 (NSW)	30/04/1974	Forked Lagoon, "Wernadinga", Burke, Qld	OR936242	N.A.
V09	*V. caulescens* F.M.Bailey & F.Muell.	Jacobs, S.W.L. 9934 (NSW)	17/06/2008	NW of Chillagoe, Cook, Qld	OR936243	N.A.
V10	*V. caulescens* F.M.Bailey & F.Muell.	Jacobs, S.W.L. 5368 (NSW)	29/07/1987	N of Starcke River, Cook, Qld	OR936244	N.A.
V11	*V. caulescens* F.M.Bailey & F.Muell.	Forster, P.I. 21088 (MEL)	24/05/1997	Hells Gate on Cliffdale Creek, Burke, Qld	OR936245	N.A.
V17	*V. caulescens* F.M.Bailey & F.Muell.	Craven, L. 4757 (CANB)	14/07/1977	Day Lagoon, McArthur River, NT	OR936250	N.A.
V01	*V. caulescens* F.M.Bailey & F.Muell.	Jobson, R.W. 4193 (NSW)	29/06/2022	Batavia Downs, Cook, Qld	OR936236	OR940931
V04	*V. caulescens* F.M.Bailey & F.Muell.	Nelder, J. 3806b (DNA)	8/04/1992	N of Lakefield Homestead, Cook, Qld	OR936239	N.A.
V19	*V. caulescens* F.M.Bailey & F.Muell.	Paijmans, K. 2870 (CANB)	12/08/1978	ESE of 'Breeza Plains' homestead, NT	OR936251	N.A.
V14	*V. kristinae* R.W.Jobson & Dunning	Fryxell, P.A. 4067 (CANB)	11/05/1983	Mitchell Plateau, NW Kimberley, WA	OR936247	OR940935
V15	*V. kristinae* R.W.Jobson & Dunning	Fryxell, P.A. 4139 (CANB)	15/05/1983	Carson River Station, North Kimberley, WA	OR936248	OR940936
V32	*V. kristinae* R.W.Jobson & Dunning	Jobson, R.W. 4360 (NSW)	24/05/2023	Airport Swamp, Mitchell Plateau, WA	OR936260	OR940942
V02	*V. kristinae* R.W.Jobson & Dunning	Barrett, R.L. 4664 (NSW)	24/04/2008	Doongan Station, North Kimberley, WA	OR936237	OR940932
V03	*V. kristinae* R.W.Jobson & Dunning	Jacobs, S.W.L. 8049 (NSW)	20/05/1996	Airport Swamp, Mitchell Plateau, WA	OR936238	OR940933
V12	*V. kristinae* R.W.Jobson & Dunning	Kenneally, K.F. 7144 (CANB)	9/02/1979	Mitchell Plateau, NW Kimberley, WA	OR936246	OR940934
V20	*V. nana* R.Br.	Sands, M.J.S. 5090 (CANB)	13/07/1988	King Leopold Ranges, West Kimberley, WA	OR936252	N.A.
V21	*V. nana* R.Br.	Trudgen, M.E. 10102 (CANB)	10/07/1991	SW of Pannawonica, WA	OR936253	N.A.
V23	*V. nana* R.Br.	George, A. 13568 (CANB)	8/08/1975	Drysdale River National Park, WA	OR936255	N.A.
V33	*V. rubra* (Rendle) Les & S.W.L.Jacobs	Jobson, R.W. 4413 (NSW)	24/05/2023	W of Timber Creek, NT	OR936261	OR940943
V16	*V. triptera* S.W.L.Jacobs & K.Frank	Barker, W. 442 (CANB)	6/05/1983	E of South Alligator River, NT	OR936249	OR940937
V28	*V. triptera* S.W.L.Jacobs & K.Frank	Jacobs, S.W.L. 7971 (NSW)	5/05/1996	W of Jabiru, on the Arnhem Highway, NT	OR936256	N.A.
V29	*V. triptera* S.W.L.Jacobs & K.Frank	Barker, W. 442 (NSW)	18/05/2023	E of South Alligator River, NT	OR936257	OR940939
V30	*V. triptera* S.W.L.Jacobs & K.Frank	Jobson, R.W. 4331 (NSW)	18/05/2023	Jabiru, NT	OR936258	OR940940
V31	*V. triptera* S.W.L.Jacobs & K.Frank	Jobson, R.W. 4335 (NSW)	20/05/2023	Jabiru, NT	OR936259	OR940941

Amplification and sequencing

Amplifications were performed using the nrDNA ITS gene marker and the plastid *trnK* 5′ intron as for Branwhite et al. (2023). The *trnK* 5′ intron was amplified with primers described in Les et al. (2008) using parameters described in Shaw et al. (2005). The ITS region was amplified for all samples using the forward primer ITS5A (Stanford et al. 2000) and the universal reverse primer ITS4 (White et al. 1990). Polymerase chain reaction (PCR) conditions for ITS were performed as described in White et al. (1990).

Phylogenetic analyses

Phylogenetic analyses were performed on (1) the two individual datasets, and (2) the concatenated matrix comprising both markers. The most suitable nucleotide substitution model for each of the three markers was assessed using the Akaike information criterion (AIC) implemented in jModelTest (ver.2.1.7, see https://en.bio-soft.net/tree/MODELTEST.html, accessed 20 November 2023; Guindon & Gascuel 2003; Posada 2008). The best fit model was GTR+G+I and with a burn-in involving the first 25% of the samples, we estimated Bayesian posterior probability using MrBayes (ver. 3.2.6; Ronquist 2012), with five independent runs of 30 million generations, using four chains with sampling of trees every 1000 generations. Substitution rates and state frequencies were set to the Dirichlet distribution, with all other priors unlinked with a flat multinomial distribution. Stationarity was assessed by examining plots of the –lnL across generations in Tracer (ver. 1.6, Rambaut et al.; https://beast.community/tracer, accessed 20 November 2023). The effective sample size (ESS) was set to >1000, and these remaining trees were used to construct a 50% majority rule consensus tree, visualised using FigTree (ver. 1.4.0; http://tree.bio.ed.ac.uk/software/figtree/).

Results

Sequences and alignment

The ITS matrix was 772 bp long, of which 269 characters (35%) were parsimony informative, and the *trnK 5′* intron matrix was 1209 bp long of which 122 characters (11%) were parsimony informative. Both datasets included samples from all ingroup taxa; ITS (*n* = 93), *trnK 5′* intron (*n* = 68) (unpublished accessions shown in Table 1; published accessions listed in Les et al. 2008 and Martin & Mort 2023). The concatenated matrix contained 93 ingroup and two outgroup taxa and was 1981 bp long with 334 parsimony informative characters (17%).

Phylogenetic relationships

Phylogenetic trees were maximally topologically congruent for the individually analysed ITS and *trnK 5′* intron datasets, although the latter provided no resolution between maximally supported clades, forming a polytomy including a monophyletic *V. rubra* and two maximally supported clades of *V. triptera* (data not shown). We therefore concatenated and analysed both datasets as a single matrix (Fig. 2). The 50% consensus tree showed strongly supported major clades (posterior probability (PP) = 1.0). The phylogeny shows the well supported African/Eurasian clade of *V. spiralis* + *V. denseserrulata* is sister to a maximally supported clade (PP = 1.0) containing all other included species. The maximally supported clade (PP = 1.0) containing accessions of *V. caulescens* is sister to an unsupported clade containing two subclades; an unsupported clade of the caulescent growth form species *V. rubra* + *V. triptera*, and a fully supported clade of rosulate growth form taxa from Australian/Asian/North America (Fig. 2). The *V. rubra* clade is supported as monophyletic, while the weakly supported *V. triptera* clade (PP = 0.90) is divided into two clades representing distributions in either NT (location of type material for *V. triptera*) or the northern Kimberley region of WA (Fig. 2). Based on the strongly supported genetic division between WA and NT specimens of *V. triptera*, coupled with morphology (see below), the two clades are recognised as two species, *V. triptera* s.s. (NT) and the new species *V. kristinae* (WA). Removal of the mostly smaller morphological measurements of *V. kristinae* from the *V. triptera* protologue (Jacobs and Frank 1997), warranted a redescription of *V. triptera*.

Taxonomy

Vallisneria triptera S.W.L.Jacobs & K.A.Frank, *Telopea* 7: 114 (1997).

Type: Northern Territory: c. 5 km W. of Jabiru, Arnhem Highway, 12°39.19’S, 132°48.97’E, 5 May 1996, *S.W.L. Jacobs 7970* (holo (♀) [prepared as two parts]: NSW 430934 (sheet); NSW 706555 (spirit); iso: DNA, MEL, BRI, Z, B, K).

A male specimen was collected from the same locality: *S.W.L. Jacobs 7971* (B, BRI, DNA, NSW, Z).

Illustration. Jacobs & McColl (2011: fig. 6).

Submerged, dioecious, stoloniferous annual. *Roots* fibrous. *Leaves* cauline, alternate to sub-opposite near stem apex, 2–9 cm long, 5–12 mm wide, green to red-green; margins finely toothed at least in the upper half; apex acute; 5–7 major longitudinal veins. *Male plant* with 1 to several inflorescences in each leaf axil; numerous flowers (95–190) enclosed in a spathe; spathe ovate, 2.5–4.5 mm long, 2–3 mm diam. *Male flowers* ovoid, c. 0.5 mm long, 0.5 mm wide, uniseriate; *perianth segments* 3; anthers 2, bisporangiate; filaments appearing fused medially (like forming a ‘Y’), hairs present on the base of the androecium. *Female plant* with 1 to several simple inflorescences in each leaf axils of the upper 1/3 of the shoot, coiled peduncle ranging from 10–30 mm long; spathe thin, translucent, 4.6–5 mm long, enclosing 1 sessile flower; apex obtuse. *Female flowers* 1.2–1.7 mm long, c. 2.4 mm wide; sepals 3, elliptical, 1.6–1.9 mm long, 0.7–0.8 mm wide, apex obtuse; petals 3, inconspicuous, minute; staminodes 3, inconspicuous; stigmas 3, bifid, deeply divided or cleft, shorter than sepals, 15–25% as wide as sepals, covered with minute filiform papillae. *Fruit* ovate in outline, trigonous in transection, 3-winged at margins, wings 2–4 mm at widest point, 17–30 mm long, 5–8 mm diam, smooth, green to red-brown. *Seeds* numerous, narrow-ovoid to ellipsoid, 0.7–0.8 mm long, 0.25–0.3 mm diam, with the surface reticulate with oblong to hexagonal cells with ribbed side walls. **Figure 3.**

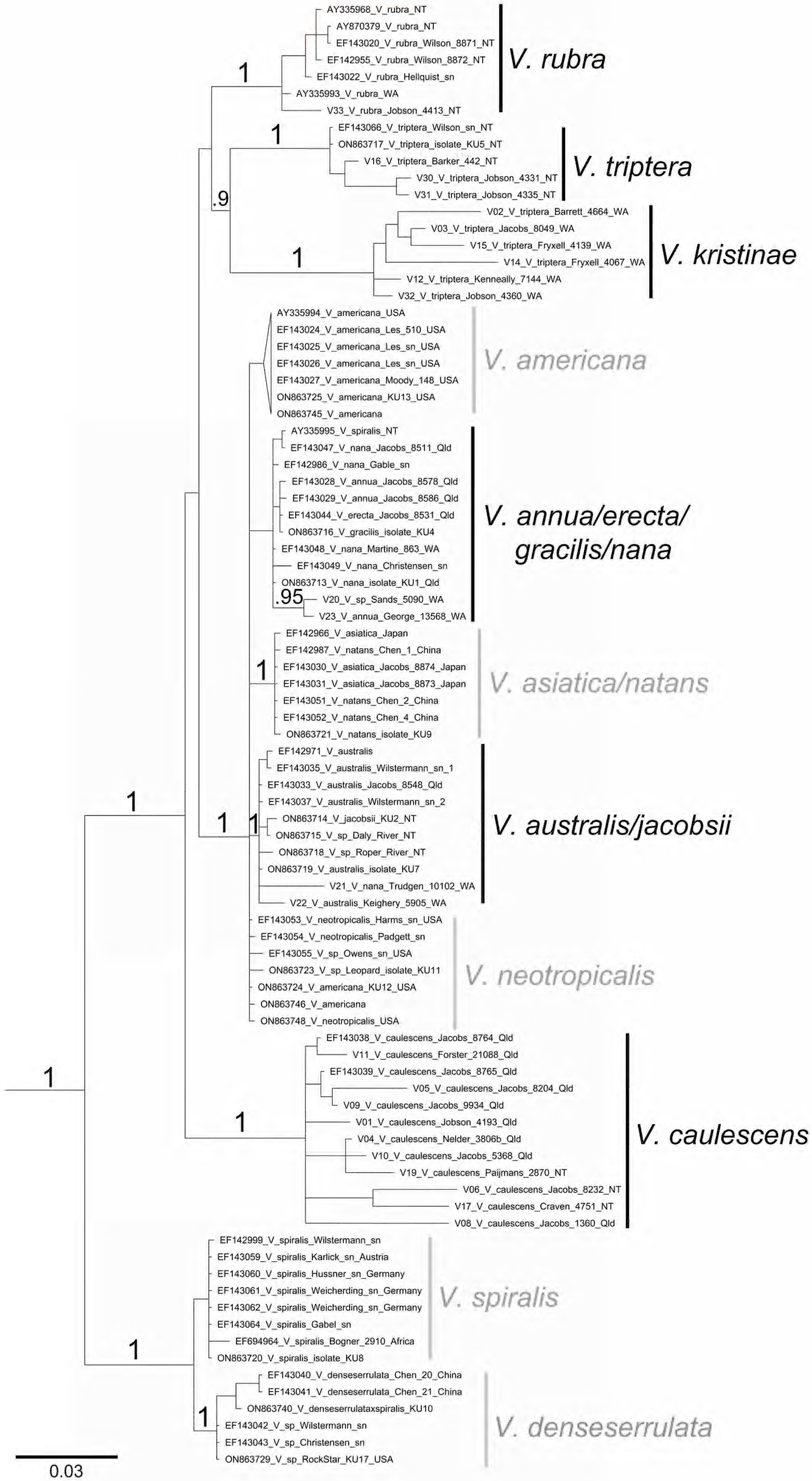

Fig. 2. 50% majority-rule Bayesian inference consensus tree for concatenated ITS/*5'trnK* data. Posterior probability (PP) support values are shown above important branches. PP = 0.95–1.00: strong support; 0.84–0.94: weak support (not shown); unsupported (not shown). Bars show clades representing taxa of Australian (black) and exotic (grey) *Vallisneria*.

Fig. 3. Holotype of *Vallisneria triptera* S.W.L.Jacobs & K.A.Frank (NSW 430934).

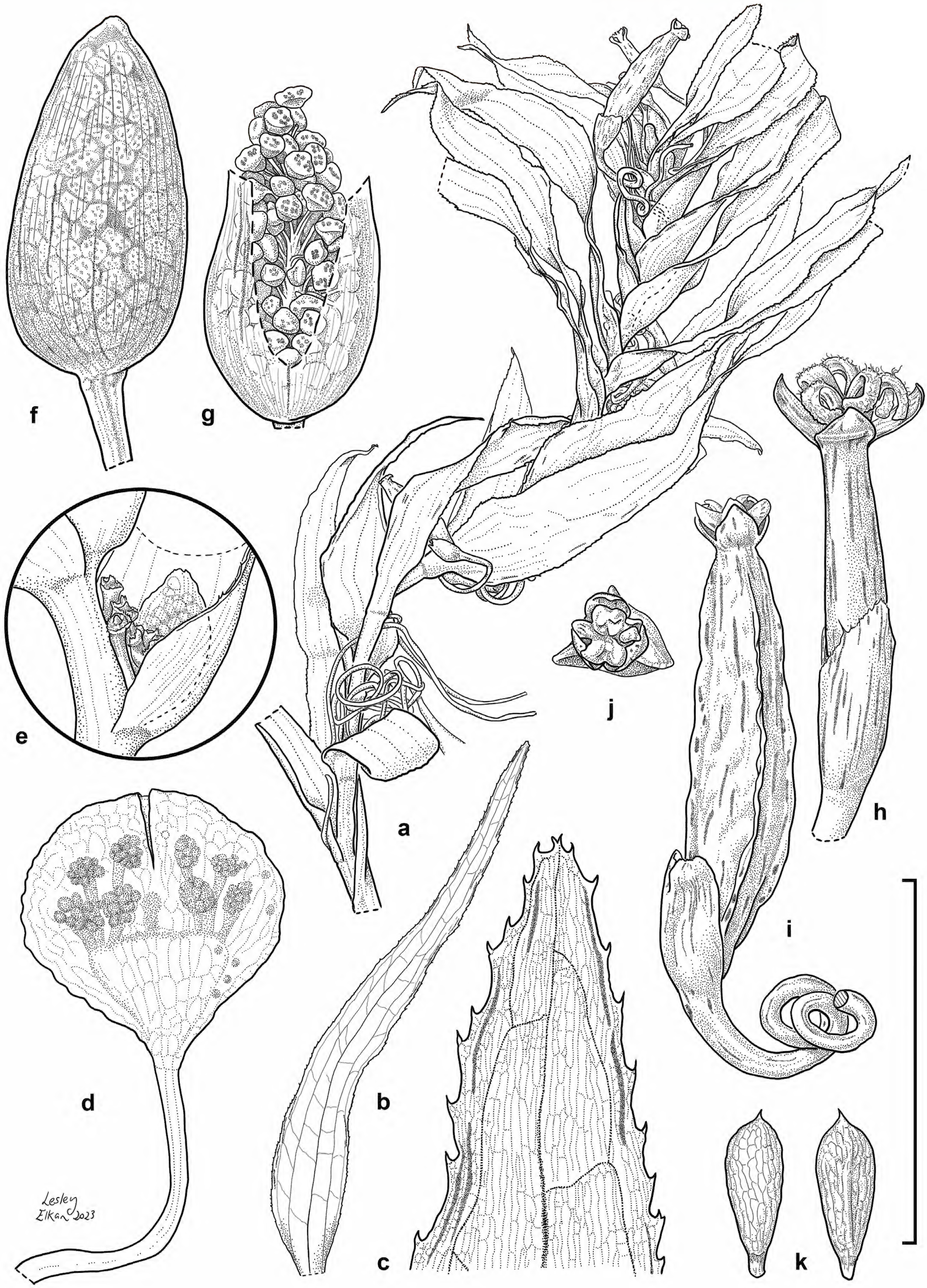

Fig. 4. *Vallisneria kristinae*. a, habit (female plant); b, leaf; c, leaf apex; d, male flower; e, leaf axil showing male spathe *in situ*; f, male spathe; g, male spathe partially excised showing male flowers; h, female flower side view; i, fruit lateral view; j, fruit dorsal view; k, seed frontal and rear view. Scale bar: a & b = 30 mm; c = 2.5 mm; d = 0.4 mm; e, i & j = 10 mm; f & g = 3.3 mm; h = 5 mm; k = 1.5 mm. Material used: *R.W. Jobson 4360 & L. Dunning* (NSW 963090 - spirit). Illustration by Lesley Elkan.

Additional specimens examined. Northern Territory, Darwin & Gulf: Arnhem Highway, 31 km E of South Alligator River, 6 May 1983, *R.M. Barker 442* (NSW 387144); Gulungul Ck, N of Arnhem Hwy, 13 Mar 1986, *I.D. Cowie 307* (DNA); between Mt Brockman and Jabiru, 21 Feb 1973, *L.A. Craven 2353* (CANB); Nanambu Ck, 27 Mar 1981, *L.A. Craven 6575* (CANB); Mt Brockman, 21 Feb 1973, *C.R. Dunlop 3325* (DNA); Baralil Creek, Kakadu National Park, 15 May 1987, *S.W.L. Jacobs 4994* ♂, *4995* ♀, *4996* ♂, *5003* ♂, *5004* ♀, *G. Sainty & K.L. Wilson* (NSW).

Distribution, Ecology & Phenology. Occurs in the vicinity of Jabiru in the Northern Territory (Fig. 1). It inhabits freshwater ephemeral creeks, waterholes, swamps or billabongs. Flowers from February to May and sets fruit from April to July.

Notes. When observed in the field, *V. triptera* is unlikely to be confused with any other species due to its broadly winged, trigonous mature fruit (Fig. 3). This is particularly the case when compared to the thinly winged trigonous fruit of *V. kristinae* (Fig. 4), the bipartite fruit of *V. caulescens*, and the cylindrical fruit of *V. rubra* (Jacobs & McColl 2011, 2023).

Conservation status. The current study proposes to geographically delimit *V. triptera* to a few sites in the vicinity of Jabiru, NT (Fig. 1). Based on previous surveys and collections, *V. triptera* is likely very localised, and very rare at the known sites. Several of the sites are within crown land at Jabiru, while others are within the boundary of Kakadu National Park. It is currently considered Near Threatened in the Northern Territory, under the *Territory Parks and Wildlife Conservation Act* (Woinarski & Wunderlich 2014) and we recommend a reassessment of this conservation status.

Vallisneria kristinae R.W.Jobson & Dunning, ***sp. nov.***

Type: Western Australia: Scull Creek camp and trap site, Doongan Station, 15°12'35.8"S, 125°43'39.2"E, 24 Apr 2008, *R.L. Barrett RLB 4664* (holo (♀): NSW929006; iso (♀): PERTH 08103259).

Diagnosis. Similar to *V. triptera* with trigonous, winged fruit, but differs in having fruit only weakly winged, and lanceolate in outline, 10–15 mm long; leaves up to 50 mm long; and male flowers 0.2 mm long.

Submerged, dioecious, stoloniferous annual. *Roots* fibrous. *Leaves* cauline, alternate to subopposite near stem apex, 20–50 mm long, 5–9 mm wide, red-green, entire margin finely toothed; apex obtuse or acute, with 3–5 major longitudinal veins. *Male plant* with 1–4 inflorescences in each leaf axil; numerous flowers (120–180) enclosed in each spathe; spathe ovate, 2.8–3.0 mm long, 1.4–1.7 mm diam. *Male flowers* ovoid, c. 0.2 mm long, c. 0.25 mm wide; *perianth segments* 3 (only observed in fused state); anthers 2, bisporangiate, filaments not clearly observed. *Female plant* with 1–5 inflorescences per leaf axil of the upper 1/3 of the shoot, coiled peduncle ranging from 10–100 mm long; spathe enclosing ¾ of ovary, 1 sessile flower, 3.1–3.6 mm long, obtuse, thin, translucent. *Female flowers* 1.1–1.3 mm long, c. 1.4 mm wide; *sepals* 3, ovate, c. 0.9 mm long, c. 0.4 mm wide, apex acute; *petals* 3, inconspicuous, minute; staminodes 3, inconspicuous; stigmas 3, bifid, deeply divided, ± length of sepals, upper surface minutely papillose. *Fruit* lanceolate in outline, trigonous in transection, 3-winged at margins, 10.0–15.2 mm long, 1.9–2.2 mm diam, wings 0.08–0.12 mm at widest point, surface slightly undulate, green with red flecks. *Seeds* numerous, ovoid, 0.45–0.60 mm long, 0.20–0.21 mm diam., with reticulate surface. **Figure 4**.

Etymology. The specific epithet *kristinae* honours Mrs Kristina McColl (nee Frank; curator at the National Herbarium of New South Wales, Botanic Gardens of Sydney) whose work on *Vallisneria* was integral in defining *V. triptera* and establishing a taxonomic treatment of the genus in Australia.

Additional specimens examined. Western Australia: Gardner: Kalumburu Community, 3 Apr 2000, *K.F. Kenneally 9820* (PERTH); Airfield Swamp, c. 5 km N of Mining Campsite, Mitchell Plateau, 21 Apr 1982, *K.F. Kenneally 8043* (CANB); Airfield Swamp, c. 5 km N of Mining Campsite, Mitchell Plateau, 20 Apr 1996, *S.W.L. Jacobs 8044* (NSW 406176); Mitchell R. above falls, 19 May 1996, *S.W.L. Jacobs 8041* (NSW); Carson River Station, 14 km S of Carson River Homestead, 15 May 1983, *P.A. Fryxell 4139 & L.A. Craven* (CANB); near Mining Campsite, Mitchell Plateau, 11 May 1983, *P.A. Fryxell 4067 & L.A. Craven* (CANB); Airfield Swamp, Mitchell Plateau, 20 May 2023, *R.W. Jobson 4360 & L.T. Dunning* ((a) female plants; (b) male plants; NSW 963090); c. 24 km WSW of old Theda Homestead on the Kalumburu Road, 16 Apr 2015, *R.W. Jobson 2672 & W. Cherry* (NSW 934780).

Distribution, Ecology & Phenology. Restricted to the Kimberley region of Western Australia (Fig. 1). Inhabits shallow freshwater ephemeral creeks and swamps (Fig 6). Flowers from February to May with mature fruit observed between April and July.

Conservation status. Although there are 14 collections from across the North Kimberley region, most are from the same vicinity at Airfield Swamp, suggesting it is likely to be regionally and locally rare. Eight of the collected specimens represent several sites that are conserved within the Mitchell River National Park at Mitchell Plateau (Airfield Swamp), while all other accessions were collected from non-protected leasehold land from near Kalumburu (*Kenneally 9820*), south-west to just north of Prince Regent National Park (*R.L.Barrett 4664*). Further field survey of this species both locally and across its distribution is required for better assessment of conservation status. We therefore recommend that this species be listed as Data Deficient in WA under either Priority code P2 or P3.

Discussion

The Bayesian analysis of the combined ITS + *trnK 5′* intron shows that samples of each of the three species *V. rubra*, *V. kristinae* and *V. triptera* each form a maximally supported monophyletic clade (PP = 1.0; Fig. 2). The distribution of *V. rubra* overlaps that of both of the latter species providing the possibility one of these species is derived through hybridization with *V. rubra*. When analysed individually the maternally inherited plastid *trnK 5′* dataset provided no resolution between maximally supported clades within a polytomy representing a monophyletic *V. rubra*, *V. kristinae*, and *V. triptera* respectively (data not shown). Under a scenario of hybridization between *V. rubra* and either *V. kristinae* or *V. triptera*, we would expect a closer relationship with its theoretical maternal parent. The individually analysed ITS phylogeny shows the same phylogenetic topology as that of the combined tree and provides the information that led to the ancestral relationships between the three taxa (Fig. 2). Under the likely scenario in which the nuDNA ITS is biparentally inherited,

and the plastid *trnK 5′* is maternally inherited we would expect to see any hybridization drive discordance in the topology of, or within, the three clades. However, apart from the lack of resolution in the plastid tree, we observed no discordance between the two tree topologies at an intraspecific level, discounting the possibility of recent hybrid origins (data not shown). Regardless, a single observation of potential hybridization between *V. rubra* and *V. triptera* was recorded by L.A. Craven in 1983 (*Craven 6576*, NSW 691255) where these species co-occur in a small creek near Jabiru, Northern Territory (Les et al. 2008; Martin & Mort 2023). This potential hybrid specimen (*Craven* 6576) has not been included in previous molecular phylogenetic studies, and although we were able to amplify and sequence it for the paternally inherited nuclear ITS (sequence available upon request), we failed to amplify the maternally inherited *trnK 5′*. Although the ITS sequence was found to be nested within the *V. rubra* clade, we also observed several polymorphisms in the ITS chromatogram linking it to *V. triptera* (data not shown). For this reason, we did not include *Craven 6576* in the current phylogeny, and we intend on presenting a more thorough analysis in future work. There have been no observations of such co-occurrence or potential hybridization occurring in Western Australian populations of *V. rubra* and *V. kristinae*.

All three species, *V. rubra*, *V. kristinae* and *V. triptera*, have a cauline vegetative growth form, anchored to the substrate via fibrous roots. The overall plant habit of *V. kristinae* and *V. triptera* is generally more robust (length of leaves ranging from 20–90 mm) than *V. rubra*, (leaves 20–30 mm long). Both *V. kristinae* and *V. triptera* differ from *V. rubra* in the shape of their fruit being trigonous 3-winged vs. non-winged and cylindrical (Fig. 5; McConchie 1983; Jacobs & Frank 1997; Jacobs & McColl 2011).

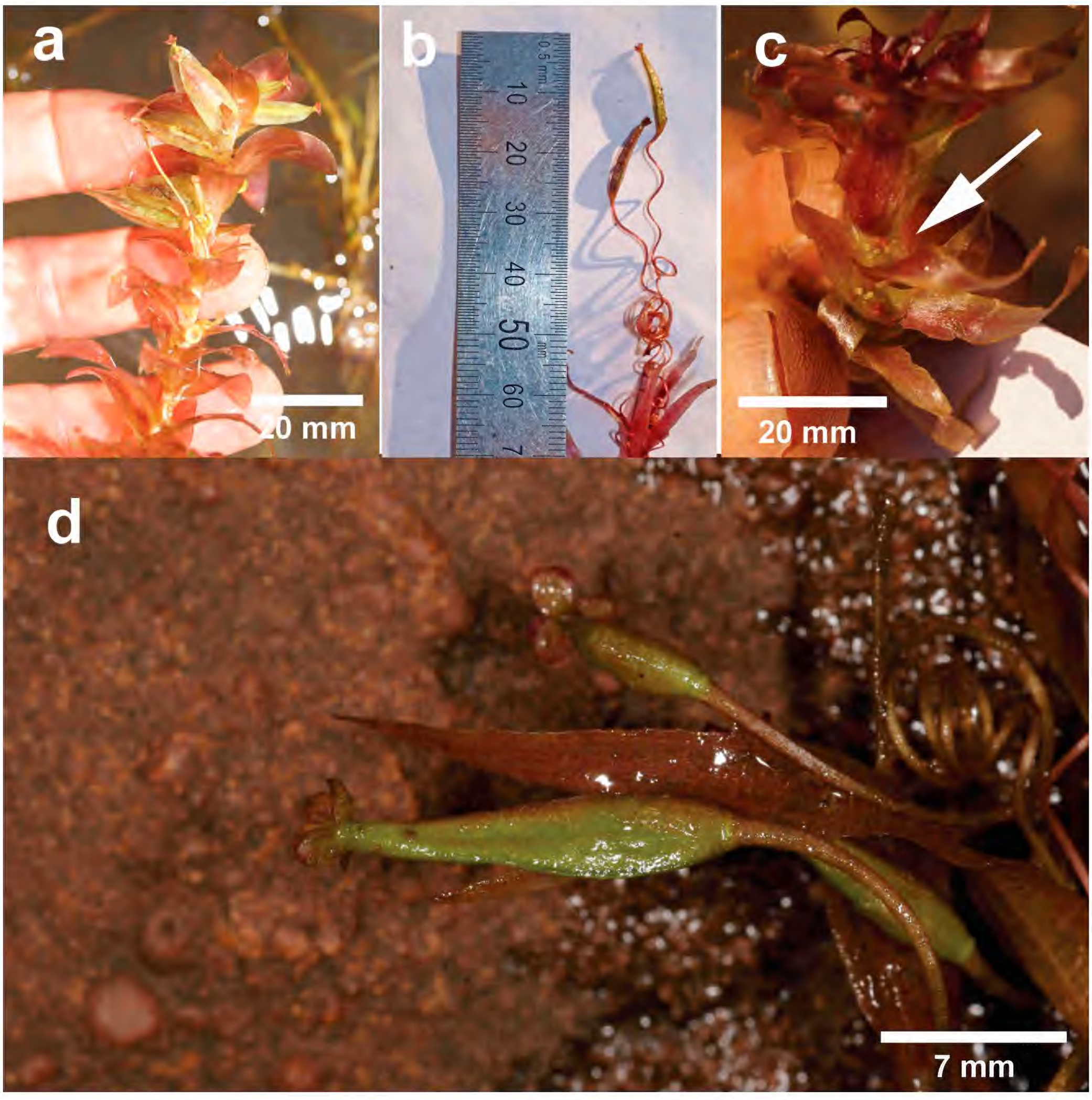

Fig. 5. Mature fruit of *Vallisneria triptera* a, *V. kristinae* b. Male plant of *V. kristinae* with spathe of flowers in leaf axil (arrow) c. mature fruit of *V. kristinae* at Theda Station d. Images: a = R. Jobson (*R.W. Jobson 4336 & L. Dunning*); b–c = R. Jobson (*R.W. Jobson 4360 & L. Dunning*); d = R. Barrett (*R.L.Barrett RLB 4664*). Scale bars shown.

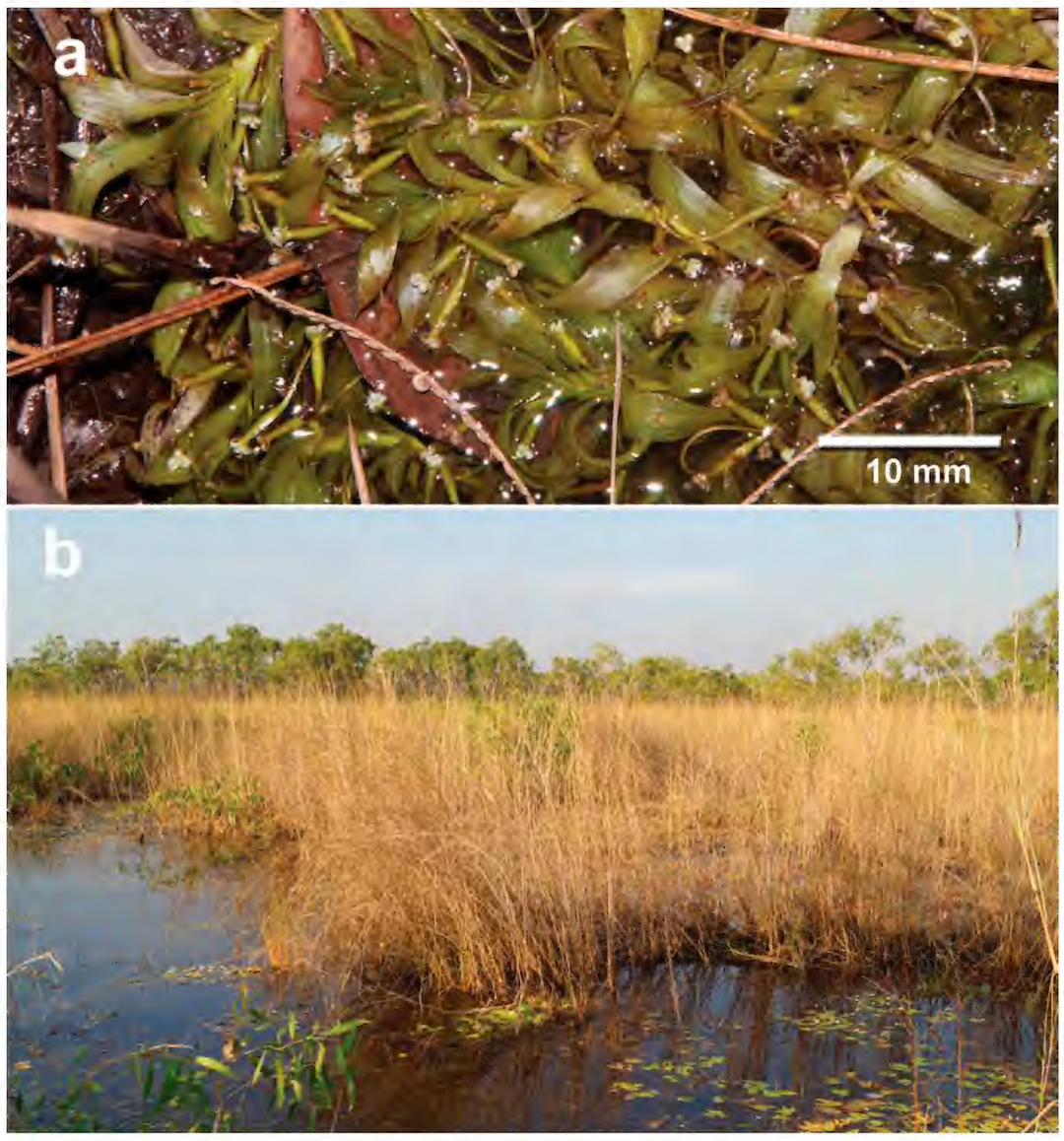

Fig. 6. *Vallisneria kristinae* habit at type site (a) and habitat on Mitchell Plateau (b). Images: a = R. Barrett (*R.L. Barrett RLB 4664*); b = R. Jobson (*R.W. Jobson 4360 & L. Dunning*). Scale bars shown.

Vegetative and sexual organs of *V. kristinae* are generally smaller than those of *V. triptera* (Figs 5 & 7). Female flowers of *V. kristinae* are c. 1.4 mm wide with ovate sepals (c. 0.9 mm long, c. 0.4 mm wide) vs. flowers of *V. triptera* c. 2.4 mm wide with elliptical sepals (1.6–1.9 mm long, 0.7–0.8 mm wide). Male flowers of *V. kristinae* are also smaller (0.2 mm long, c. 0.25 mm wide) than those of *V. triptera* (<0.5 mm long, 0.5 mm wide; Fig. 7).

Vallisneria kristinae is similar to *V. triptera* with both possessing trigonous 3-winged fruit. However, the most salient difference between the two species is that *V. kristinae* has the fruit weakly winged, lanceolate in outline and small (10–15 mm long, 1.9–2.2 mm diam.) while in *V. triptera* they are broadly winged, ovate in outline, and larger (17–30 mm long, 5–8 mm diam). Seeds are also smaller in *V. kristinae* (0.45–0.60 mm long, 0.20–0.21 mm diam.) vs. those of *V. triptera* (0.7–0.8 mm long, 0.25–0.3 mm diam.) (Fig. 7).

Although the original description of *V. triptera* (Jacobs & Frank 1997) accounts for the overall small vegetative and sexual organs of the Kimberley plants (i.e., *V. kristinae*), it does not include the weakly winged mature fruit and small seeds. This is likely due to the observed rarity of mature fruit on specimens collected in WA with the few observable fruit probably assumed by the authors to be large, immature flowers.

Our *Vallisneria* phylogeny based on the combined sequence data (Fig. 2) supports the results of Martin and Mort (2023). The phylogeny shows the newly described species *V. jacobsii* nested within a clade containing accessions of *V. australis*. In this study we have not been able to examine morphological characters for inclusion of *V. jacobsii* in our key. Our main concern involved the taxonomic description of Martin and Mort (2023) that states the basal leaf arrangement 'appears distichous' as opposed to singularly rosulate in *V. australis*. Based on the degree of doubt regarding the presence of this key character, the populations of *V. jacobsii* requires further examination.

Key to species of *Vallisneria* in Australia (modified from Jacobs and McColl 2011)

1a Leaves all cauline; facultative annuals **2**

1b Leaves basal, tufted; annuals or perennials **5**

2a Fruit not winged, leaf blade nearly filiform (0.1–0.2 mm wide) ..... ***V. rubra***

2b Fruit winged, bi- or tripartite in transverse section, leaf blade flat (4.5–15 mm wide) **3**

3a Fruit 2-winged, flattened, usually >40 mm long; female flowers with 2 perianth segments ..... ***V. caulescens***

3b Fruit 3-winged, trigonous; female flowers with 3 perianth segments **4**

4a Mature fruit broadly winged, 7.0–8.0 mm wide, 17–30 mm long ..... ***V. triptera***

4b Mature fruit slightly winged, 3.0–3.5 mm wide, 10–15 mm long ..... ***V. kristinae***

5a Plants facultatively annual (commonly in ephemeral waterbodies); leaf-tips long-acute; female tufts commonly producing numerous (>12) flowers at maturity in first year while still quite small ..... ***V. annua***

5b Plants normally perennial; leaf tips acute or obtuse; female tufts not flowering until plant is several years old and then only producing few flowers (<12) at any one time **6**

6a Stranded plants with erect, stiff, acute leaves; plants in deeper water with obtuse leaves (Daintree R., N Qld) ..... ***V. erecta***

6b All leaves lax, and either all acute or all obtuse **7**

7a Leaves obtuse; filaments in male flower fused for about 75% of their length; leaves often >10 mm wide ..... ***V. australis***

7b Leaves acute, with or without a fine apical mucro; filaments in male flower free to fused for about 75% of their length; leaves often <1 cm wide **8**

8a Leaves usually 3–10 mm wide, mostly obtuse, not with a fine apical mucro; various habitats of the Australian Monsoon Tropics and sub tropics ..... ***V. nana***

8b Leaves <3 mm wide, with a fine apical mucro; plants of fast-flowing shallow water of the Australian Wet Tropics biome, often in shaded habitats ..... ***V. gracilis***

Acknowledgments

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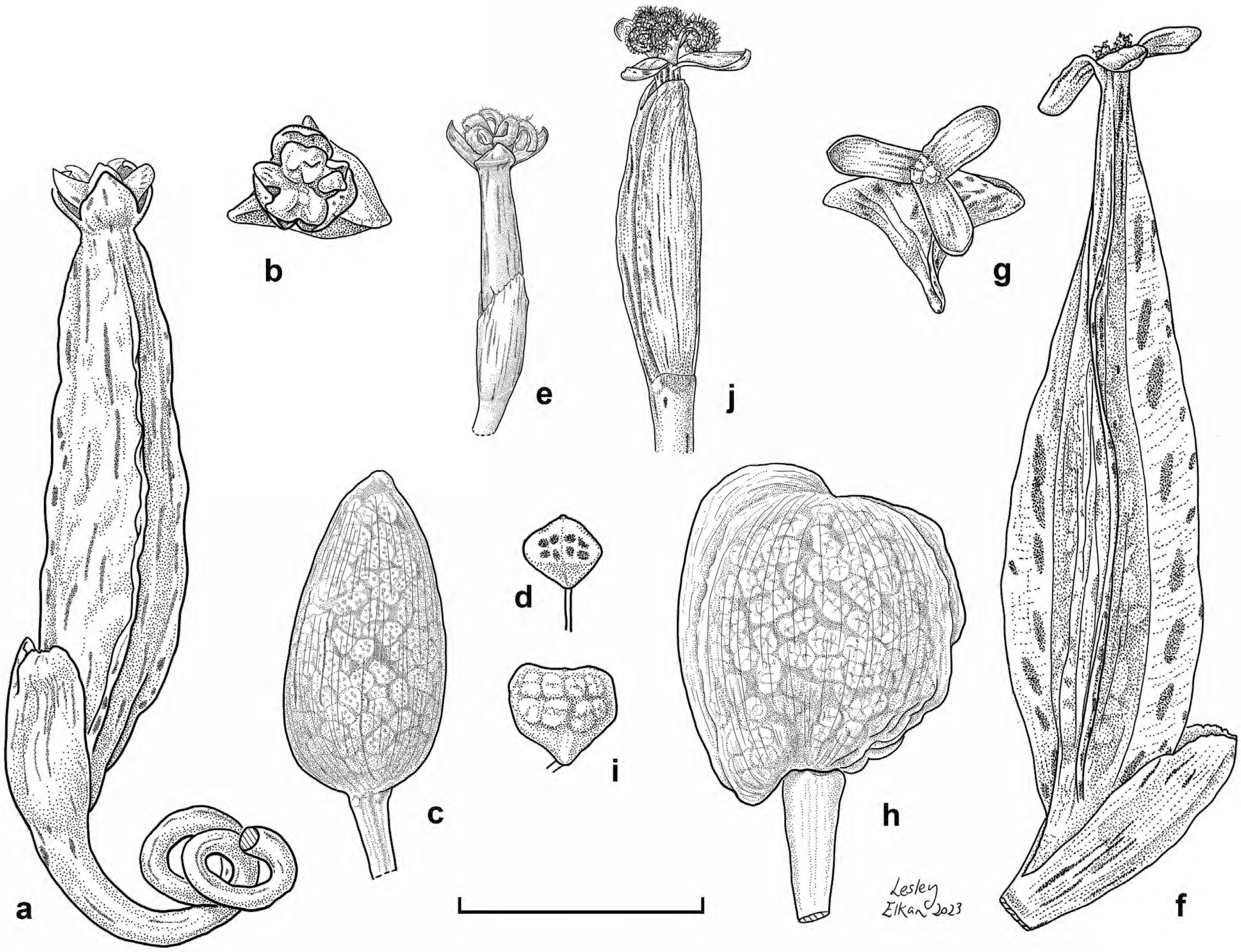

Fig. 7. Comparison of *Vallisneria kristinae* (a–e), *V. triptera* (f–i), a & f, fruit in situ; b & g, fruit dorsal view; c & h, male spathe; d & i, male flower lateral view; e & j, female flower lateral view. Scale bar: a, b, e, f, g, j = 5 mm; c & h = 2.5 mm; d & i = 1.0 mm. Material used: a–e = *R.W. Jobson 4360 & L. Dunning* (NSW 963090 - spirit); f, g, j = *S.W.L. Jacobs 4994* (spirit 3233; NSW 387142); h, i = *R.W. Jobson 4335* (NSW 963079).

References

Branwhite B, Jobson RW, Albrecht DE (2023) *Patersonia rosea* (Iridaceae, Patersonioideae) a new species from the New South Wales central and lower north coast regions. *Telopea* 26: 61–73. DOI

Guindon S, Gascuel O (2003) A simple, fast, and accurate method to estimate large phylogenies by maximum likelihood. *Systematic Biology* 52: 696–704. DOI

Jacobs SWL, Frank KA (1997) Notes on *Vallisneria* (Hydrocharitaceae) in Australia, with descriptions of two new species. *Telopea* 7: 111–118. DOI

Jacobs SWL, McColl KA (2011) Hydrocharitaceae. In Wilson AJG (ed.) *Flora of Australia* 39: 25–26.

Jacobs SWL, McColl KA (2023) *Vallisneria*. In Wilson AJG (ed.) *Flora of Australia*. *Australian Biological Resources Study, Department of Climate Change, Energy, the Environment and Water: Canberra*. URL [Date Accessed: 17 December 2023]

Jobson RW, Baleeiro PC, Reut MS (2017) Molecular phylogeny of subgenus *Polypompholyx* (*Utricularia*; Lentibulariaceae) based on three plastid markers: diversification and proposal for a new section. *Australian Systematic Botany* 30: 259–278. DOI

Les, DH, Jacobs SW, Tippery NP, Chen L, Moody ML, Wilstermann-Hildebrand M (2008) Systematics of *Vallisneria* (Hydrocharitaceae). *Systematic Botany* 33: 49–65. DOI

Martin AP, Mort MK (2023) *Vallisneria* (Hydrocharitaceae): novel species, taxonomic revisions, and hybridization. *Aquatic Botany* 188: 103669. DOI

McConchie CA (1983) Floral development of *Maidenia rubra* Rendle, (Hydrocharitaceae). *Australian Journal of Botany* 31: 585–603. DOI

McConchie CA, Kadereit JW (1987) Floral structure of *Vallisneria caulescens* Bailey & F. Mueller. *Aquatic Botany* 29: 101–110. DOI

Posada D (2008) jModelTest: phylogenetic model averaging. *Molecular Biology and Evolution* 25: 1253–1256. DOI

Ronquist F, Teslenko M, van der Mark .P, Ayres DL, Darling A, Höhna S, Larget B, Liu L, Suchard MA, Huelsenbeck JP (2012) MRBAYES 3.2: Efficient Bayesian phylogenetic inference and model selection across a large model space. *Systematic Biology* 61: 539–542. DOI

Shaw J, Shafer HL, Leonard OR, Kovach MJ, Schorr M, Morris AB (2005) The tortoise and the hare II: relative utility of 21 noncoding chloroplast DNA sequences for phylogenetic analysis. *American Journal of Botany* 92: 142–166. DOI

Shen X-S (2000) A new species of *Vallisneria* (Hydrocharitaceae) from China. *Acta Botanica Boreali-Occidentalia Sinica*. *Yangling*. 20: 889–891.

Shen X-S (2001) A new species of *Vallisneria* (Hydrocharitaceae) from Anhui Province, China. *Acta Phytotaxonomica Sinica* 39: 571–574. URL

Stanford AM, Harden R, Parks CR (2000) Phylogeny and biogeography of *Juglans* (Juglandaceae) based on *matK* and ITS sequence data. *American Journal of Botany* 87: 872–882. DOI

White TJ, Bruns T, Lee S, Taylor JW (1990) Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In *PCR protocols: a guide to methods and applications*. (Eds MA Innis, DH Gelfand, JJ Sninsky, TJ White) pp. 315–322. (Academic Press, Inc.: New York, NY, USA)

Woinarski JCZ, Wunderlich S (2014). A strategy for the conservation of threatened species and threatened ecological communities in Kakadu National Park 2014-2024. Available at: URL [accessed 18 March 2024]

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Lasiopetalum prodigiosum (Malvaceae: Lasiopetaleae), a new species from central-eastern New South Wales to south-eastern Queensland

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Keywords: Malvaceae, *Lasiopetalum*, taxonomy

Abstract

Lasiopetalum prodigiosum C.F.Wilkins, L.M.Copel. & K.A.Sheph., is recognised here as a new species that is currently only known from eight populations across central-eastern New South Wales to south-eastern Queensland. This species has historically been confused with *L. ferrugineum* Sm. ex Andrews and *L. macrophyllum* Graham but is supported as distinct based on molecular and morphological data. This paper provides diagnostic features that distinguish *L. prodigiosum* from other known species, as well as notes on its current distribution, and a key to allied species.

Introduction

Lasiopetalum Sm. is an Australian endemic genus, consisting of *c.* 74 known taxa, in the tribe Lasiopetaleae J.Gay (Malvaceae Juss.). Western Australia is the centre of morphological diversity for the group, with 46 named and four unpublished taxa (with informal phrase-names) currently known (Western Australian Herbarium 1998–), while in eastern Australia, approximately 10 taxa, including two unpublished taxa, namely *Lasiopetalum* sp. Proston (J.A.Baker 17) Qld Herbarium and *L.* sp. Coochin Hills (L.S.Smith 14050), are recognised (Council of Heads of Australasian Herbaria 2024; Guymer 2022; PlantNet 2024; VicFlora 2024).

Lasiopetalum ferrugineum Sm. ex Andrews, was recently designated as the lectotype for *Lasiopetalum* (Shepherd and Wilkins 2018) and currently two varieties are recognised (*L. ferrugineum* Sm. ex Andrews var. *ferrugineum* and *L. ferrugineum* var. *cordatum* Benth.); however, further variation within this broadly defined taxon has been noted, with small and large-flowered forms sometimes recognised (Harden 1990). Field collections for the ongoing revision of the genus (Shepherd and Wilkins in prep.), in conjunction with the examination of herbarium specimens from across eastern Australia, has made it clear that a new taxon from northern New South Wales and southern Queensland may warrant taxonomic recognition. This taxon had previously been treated as a large-flowered variant of *L. ferrugineum* var. *cordatum* or sometimes included under *L. macrophyllum* Graham.

Samples of this potentially new taxon (*C. Wilkins & E. Bennett* CW NSW 37; *C.F. Wilkins, B.A. Whitlock & L. Copeland* CW 2054) were subsequently included in a project that used Angiosperm353 bait capture data to investigate phylogenetic and taxonomic

Wilkins CF, Copeland LM and Shepherd KA (2024) *Lasiopetalum prodigiosum* (Malvaceae: Lasiopetaleae), a new species from central-eastern New South Wales to south-eastern Queensland. *Telopea* 27: 41–46. doi:10.7751/telopea17988

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relationships within *Lasiopetalum* and allied genera. Analyses of these data placed these samples as sister to a subclade including *L. ferrugineum* and other allied species recognised in the affinities section below (B. Anderson pers comm.). An examination of all relevant herbarium collections, including closer comparison of these northern plants with material from the type locality of *Lasiopetalum ferrugineum* var. *cordatum* in the Blue Mountains, has confirmed the distinctiveness of this taxon, named herein as *L. prodigiosum* C.F.Wilkins, L.M.Copel. & K.A.Sheph.

Methods

Collections of *Lasiopetalum* held in CANB, MEL, NE, NSW, and PERTH were examined, along with the relevant literature pertaining to most currently recognised species in the genus. Further material may be present in the collections held at BRI but these have not been examined. Type specimens of allied taxa were viewed online via JSTOR Global Plants (https://plants.jstor.org/). Measurements were scored from freshly collected material, ethanol-preserved material and dried and rehydrated herbarium material. Due to the variation in size often evident in juvenile leaves for the genus, measurements were made from mature leaves only.

Distribution maps were created using QGIS version 2.18.16 and include version 7 of the Interim Biogeographic Regionalisation for Australia (IBRA) bioregions (Department of the Environment 2013). Botanical districts included in the selected specimens follow those originally proposed by L. Halasz (https://www.anbg.gov.au/cpbr/anhsir/anhsir-manual/botanical-districts.html).

Taxonomy

Lasiopetalum prodigiosum C.F.Wilkins, L.M.Copel. & K.A.Sheph. ***sp. nov.***

Type: New South Wales: Northern Tablelands, Gibraltar Range National Park, 30 October 2004, *C.F. Wilkins 2054, B.A. Whitlock & L. Copeland* (holo: NSW 837867; iso: PERTH 07971087).

Erect *shrub* 0.5–1.5 m high, 0.5–1 m wide. *Young stems* with a ferruginous tomentum of scattered, stalked (*c*. 0.6 mm long), multi-angulate or appressed stellate hairs with *c*. 12 arms (each to 0.4 mm long), over a layer of dense, smaller, white, stellate hairs; late-glabrescent. *Stipules* absent. *Petioles* 12–29.3 mm long. *Leaves* narrowly ovate to ovate, discolorous, 33–93 mm long, 20–51 mm wide, base cordate, margin entire or sinuate, flat or scarcely recurved, apex acute; abaxial surface with a tomentose indumentum of white (sometimes with pale ferruginous centres), stalked (*c*. 0.3 mm long) or sessile, multi-angulate, stellate hairs with *c*. 12 arms (each to 0.4 mm long), over a layer of smaller, dense, white, appressed stellate hairs; adaxial surface with dense, white (sometimes with ferruginous centres), appressed stellate hairs with *c*. 10 arms (each to 0. 2 mm long); early glabrescent. *Inflorescence* a moderately loose dichasium, 19–35 mm long, with 4 or 5(–8) flowers. *Peduncles* 5–15 mm long, indumentum as in young stem except hairs sessile. *Pedicels* 1.4–5 mm long. *Bracts* narrowly ovate to linear, 1.5–4.5 mm long, 0.3–0.7 mm wide. *Epicalyx bracts* 3, attached directly below calyx, non-petaloid, scarcely fused at base (to *c*. 0.5 mm long), narrowly triangular to narrowly ovate, 2.4–5.2 mm long (central bract longest), 0.6–1.5 mm wide. *Calyx* 5-merous, base indumentum rusty tomentose, apex creamy white, inner surface whitish green, 9.1–14.1 mm long; calyx tube 2.3–3 mm long; lobes ovate 6.5–7.3 mm long, 5.1–6.7 mm wide, widths equal, apex acute; outer surface with base and central lobe densely hairy, with ferruginous, stalked (to 0.3 mm long) or sessile, multi-angulate, stellate hairs with *c*. 12 arms (each arm to 0.7 mm long), over a dense layer of smaller, white, stellate hairs, towards the margin of each lobe; inner surface without a prominent central rib, base and central lobe with a dense tomentum of white, brittle, appressed, stellate hairs with *c*. 10 arms (each to 0.3 mm long), glabrous towards lobe margins and apex. *Petals* dark red, obovate, 1.5–3.1 mm long, 0.5–1.3 mm wide, glabrous or abaxial surface with scattered, white, stellate hairs. *Hypogynous cup, staminal tube* and *staminodes* absent. *Staminal filaments* 2.5–4.8 mm long, glabrous. *Anthers* 5, dark red (with white apex around upwardly dehiscent pores), oblong or elliptic with an obtuse apex, 2.5–3.1 mm long, 0.8–1.2 mm wide, glabrous. *Ovary* 3- or 4-locular with 2 ovules per locule, 4.5–4.8 mm long, 4.6–5.5 mm wide; outer surface densely hairy, with stalked (*c*. 0.3 mm long), white or golden, appressed, stellate with *c*. 12 arms (each to *c*. 0.7 mm long), above a layer of smaller, brittle hairs. *Style* 0.6–2 mm long, glabrous or basal third densely hairy, with hairs white, sessile, stellate. *Fruit* ellipsoid, *c*. 4.5 mm long, *c*. 4 mm wide. *Seed* ellipsoid, *c*. 2.5 mm long, *c*. 1.3 mm wide, dark brown, smooth, densely stellate hairy; *aril* consisting of a cream cap with two lobes (*c*. 1.3 mm long). (Figures 1, 2)

Diagnostic characters: Distinguished from morphologically similar species of *Lasiopetalum* by the following combination of characters: leaves discolorous, narrowly ovate to ovate, margins entire to sinuate, apex acute, 33–93 mm long, 20–51 mm wide; inflorescence a moderately open dichasium 19–35 mm long, with 4–5(–8) rusty tomentose flowers with a creamy white apex and whitish-green inner surface; three narrowly triangular or narrowly ovate epicalyx bracts 2.4–5.2 mm long (central longer); dark red petals 1.5–3.1 mm long; calyx large, 9.1–14.1 mm long, inner surface base and central lobe with dense, white, brittle, appressed, stellate hairs, glabrous towards margins and apex, outer surface base and central lobe with dense, ferruginous, stellate hairs, with smaller, white, hairs towards the margins; staminal filaments long (2.5–4.8 mm); anthers long (2.5–3.1 mm long); ovary large (4.5–4.8 mm long, 4.6–5.5 mm wide), with dense, white or golden, appressed, stellate hairs with arms to 0.7 mm long over smaller, white, brittle, hairs; style glabrous or basal third with dense, white, stellate hairs.

Specimens examined: NEW SOUTH WALES: North Coast: North Obelisk, 2 km W of Urbenville, 13 Oct. 1990, *A.R. Bean 2496* (BRI, HO, MEL!, NSW!); Glassy Mtn, 11 km SE of Woodenbong, 1 Jun. 1999, *A.S. Benwell 123* (NE!); North Obelisk Mtn, Coutts Crown, 1.5 km WSW of Urbenville, 10 Jun. 1999, *A.S. Benwell* 125 (NE!); North Obelisk, 2 km W of Urbenville, 6 Sep. 1994, *C.F. Wilkins CW NSW 37 & E. Bennett* (PERTH!). **Northern Tablelands:** Werrikimbe National Park, 2.9 km SE of Cobcrofts Rd, along Carey's Trail, 19 Jul. 2007, *L.M. Copeland 4247 & P. Thomas* (BRI!, CANB!, NE!, NSW!) ; 19 km E of Deepwater on Miles Shaw Rd, Butterleaf, 1 Dec. 1995, *J.T. Hunter 3785* (BRI, MEL!, NE!, NSW!); Butterleaf State Forest, *c*. 20 km NE of Glen Innes, Mt Scott, 16 Jun. 1996, *J.T. Hunter 3929* (NE!); Butterleaf

State Forest, Compartment 211, 200 m SW of Scott Trig point, 18 Jun. 1996, *P.G. Richards 536, D. Moffat & J.T. Hunter* (CANB!, NE!, NSW!); Gibraltar Range, *c.* 40 miles NE of Glen Innes, s.dat., *J.B. Williams s.n.* (NE28381!); Gibraltar Range, NE of Glen Innes, s.dat., *J.B. Williams 588 & E.K. Winterholder* (NE!); Gibraltar Range, NE of Glen Innes, Feb. 1958, *E.K. Winterholder s.n.* (NE28379!); Gibraltar Range, Oct. 1958, *J.B. Williams 588A & E.K. Winterholder* (NE!). **Central Western Slopes:** Yarrawa Fire Trail, *c.* 15 km south-west of Denman, Wollemi National Park, 23 Nov. 2014, *R.L. Johnstone 3547 & W. Holzinger* (NSW!).

QUEENSLAND: Moreton: Mt Ernest, 10 Nov. 1992, *P.I. Forster 12366 & G. Leiper* (BRI, CANB, NSW 282728!, MEL!, K!).

Distribution: *Lasiopetalum prodigiosum* ranges from the far northern section of Wollemi National Park in New South Wales to south-eastern Queensland (Figure 3). Throughout its range, *L. prodigiosum* is uncommon and sporadic with effectively just eight populations currently known. We have examined very limited material from Queensland; however, specimens examined from Mount Ernest in Mount Barney National Park, are confirmed as *L. prodigiosum* (Figure 2). It is likely that plants referred to as *L. ferrugineum* var. *cordatum* in Main Range National Park by Leiper *et al.* (2017), are also referrable to *L. prodigiosum*, which based on current knowledge would be the northern limit of the species. Examination of all Queensland material is required to confirm the current range of this species.

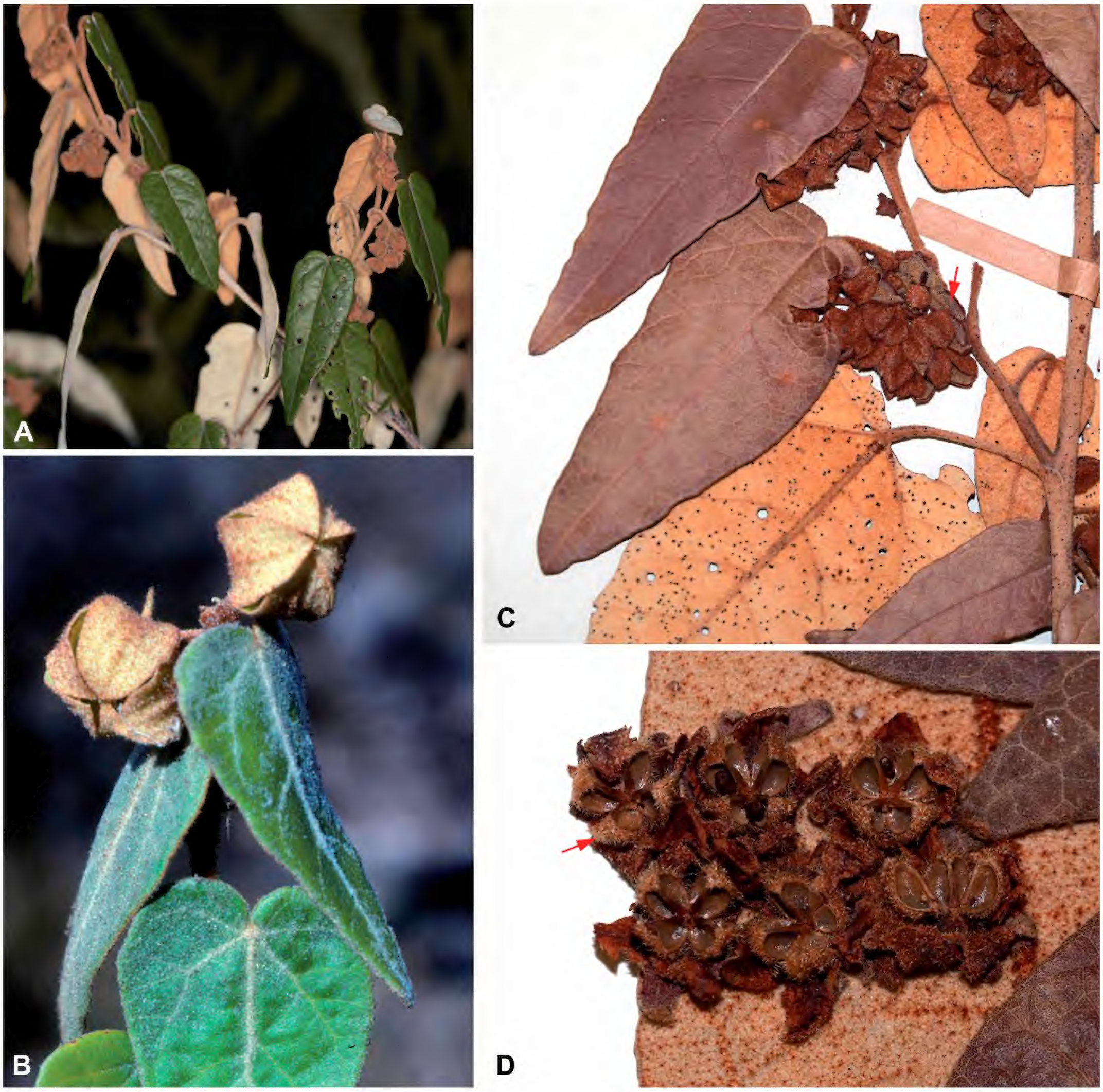

Figure 1. *Lasiopetalum prodigiosum*. A – flowering branchlet showing discolorous leaves and young flowers with dense ferruginous hairs on the outer calyx, peduncles and pedicels; B – mature flowers showing a narrow epicalyx bract (one of three) at the base of the calyx, and two large flowers with broad calyx lobes with ferruginous hairs at the base and centre with cream hairs towards the margins and apex; C – specimen with open flowers highlighting the dense stellate hairs across the whole inner surface of the calyx (red arrow); D – mature, open fruits highlighting the capsule outer surface with the mix of large stellate hairs that obscure short, brittle hairs below. Images by: A – P. Sheringham (unvouchered from Gibraltar Range); B – G. Leiper (unvouchered, Mt Ernest); C – L. Copeland (*J.B. Williams 588 & E.K. Winterholder* NE 28380); D – L. Copeland (*A. Benwell 123* NE082749A).

Figure 2. Photograph a *Lasiopetalum prodigiosum* specimen held at K (*P.I. Forster 12366 & G. Leiper*), highlighting the broad, discolorous leaves and large flowers. Image by K.A. Shepherd.

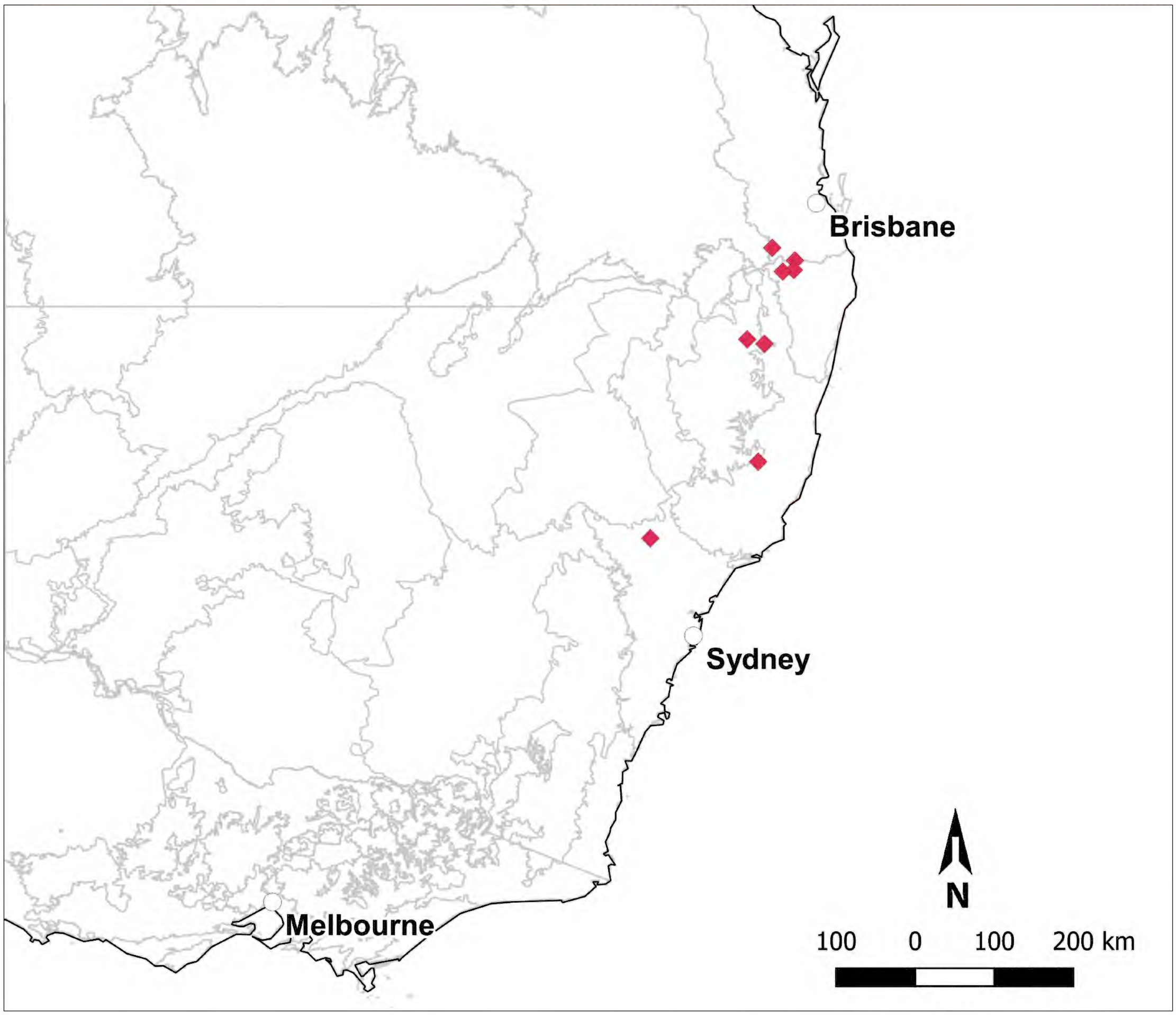

Figure 3. Distribution map of *Lasiopetalum prodigiosum* with IBRA subregions in pale grey (Department of the Environment 2013).

Habitat: This species grows in rocky areas at altitudes ranging from 500–1000 m, in shallow, brown sandy loams or grey clayey sands, over granite, sandstone, trachyte and volcanic geologies in low heathland or *Eucalyptus* woodlands associated with *Eucalyptus cameronii*, *E. williamsiana*, *Hibbertia riparia*, *Leptospermum* and *Pomaderris*.

Phenology: Flowers have been recorded from June through to December. Old fruits were present on specimens collected in June (*A.S. Benwell* 123, NE 082749A).

Conservation status: Although this species appears to be sporadic and uncommon, *Lasiopetalum prodigiosum* is represented in several conservation reserves such as Wollemi, Cottan-Bimbang, Werrikimbe, Gibraltar Range, Butterleaf, Toonumbar, Mount Barney and Main Range National Parks. Population sizes are small and are therefore vulnerable to stochastic events such as intense wildfires. A particularly intense fire in late 2019 burnt the type population in Gibraltar Range National Park and killed all adult plants, with a small number of seedling recruits only reaching maturity four years later. As such, while this species may currently be known from several populations in the reserve system, it may still be under threat and vulnerable to local extinctions.

Etymology: From the Latin *prodigiosus* (huge, enormous, wonderful), in reference to the large and striking foliage and flowers of this species compared to most other species of *Lasiopetalum*.

Affinities: Based on Angiosperm353 bait capture data *L. prodigiosum* is placed sister to a clade with other eastern states species including *L. ferrugineum* var. *ferrugineum*, *L. ferrugineum* var. *cordatum*, *L. joyceae*, *L. parviflorum*, and *L. rufum* (B.M. Anderson, pers. comm.) (*L. macrophyllum* was not sequenced).

The inner surface of the calyx of *L. prodigiosum* has dense, stellate hairs throughout (Figure 1C); a feature shared with *L. rufum*, *L. joyceae* and *L. ferrugineum*. *Lasiopetalum prodigiosum* is readily differentiated from *L. rufum* and *L. joyceae* by its large, narrowly ovate to ovate leaves (vs linear to narrowly oblong or narrowly ovate leaves) and moderately open dichasium (vs open monochasium or rarely a dichasium). *Lasiopetalum prodigiosum* has most often been confused with *L. ferrugineum* and can be

distinguished from *L. ferrugineum* var. *ferrugineum* by virtue of its inflorescence having fewer flowers (4–8 vs 8–10) as well as its larger filaments (4.5–4.8 vs (0.6–)1.1–1.3 mm long), usually larger anthers (2.5–2.8 vs 0.9–1.9(–2.8) mm long, larger ovary (4.5–4.8 vs 1.5–2.5 mm long) and less compact inflorescence. This new species can also be consistently recognised as distinct from *L. ferrugineum* var. *cordatum* as the latter has unique hairs on the ovary, which are small and brittle, while the outer surface of the ovary of *L. prodigiosum* has a mix of dense, appressed white or golden stellate hairs with arms to 0.7 mm long over smaller, brittle hairs. In addition, the inner surface of the calyx of *L. prodigiosum* has stellate hairs only while in *L. ferrugineum* var. *cordatum* fine, glandular hairs are intermixed with stellate hairs on the inner calyx.

Lasiopetalum macrophyllum and *L. parviflorum* are distinct from *L. prodigiosum*, as the base of the inner calyx in both species is glabrous with stellate hairs present only on the margins and apex, rather than having dense, stellate hairs throughout as seen in *L. prodigiosum*, *L. rufum*, *L. joyceae* and *L. ferrugineum*. *Lasiopetalum prodigiosum* can be further identified from *L. macrophyllum* by its narrowly triangular to narrowly ovate epicalyx bracts 0.6–1.5 mm wide (vs elliptic to ovate epicalyx bracts 1.3–5.3 mm wide) and from *L. parviflorum* by its broader leaves (20–46 mm wide vs 1.2–9 mm wide) and larger flowers (9.1–14.1 mm long vs 3–3.7(–5) mm long).

Notes: *Lasiopetalum ferrugineum* var. *cordatum* (*S. Bell s.n.* NSW 440805) was collected in a similar locality to *L. prodigiosum* (*R.L. Johnstone 3547 & W. Holzinger* NSW 879921) in the North Wollemi National Park, indicating that these species may co-occur.

Key to species allied to *L. prodigiosum*

1. Calyx with the inner surface glabrous, except for the stellate hairs confined to the margin and apex of each lobe
2. Leaves narrowly ovate to ovate, 25–130 mm long, 10–70 mm wide. Calyx 5.3–10.2 mm long ..... **L. macrophyllum**
2: Leaves usually linear, sometimes narrowly oblong to very narrowly elliptic, 30–70 mm long, 1.2–9 mm wide. Calyx 3–3.7(–5) mm long ..... **L. parviflorum**
1: Calyx with the inner surface covered in stellate hairs throughout
3. Leaves linear, narrowly oblong or very narrowly ovate, 1–6(–10) mm wide. Inflorescence a loose monochasium or rarely a dichasium
4. Inflorescence with 2–3(–5) flowers; calyx 4–7.5 mm long, with calyx lobes 4.4–5.4 mm wide ..... **L. rufum**
4: Inflorescence with 3–5(8) flower. Calyx (6.3–)9–12.2 mm long, with calyx lobes 8–8.3 mm wide .... **L. joyceae**
3: Leaves narrowly elliptic, narrowly oblong, narrowly ovate to ovate, 7–51 mm wide. Inflorescence a moderately loose to compact dichasium
5. Calyx inner surface with stellate hairs throughout. Ovary outer surface with large, white or golden, appressed stellate hairs over a layer of smaller, brittle, hairs
6. Inflorescence a moderately open dichasium with 4–8 flowers. Staminal filaments 2.5–4.8 mm long, anthers 2.5–3.1 mm long; ovary 4.5–4.8 mm long, 4.6–5.5 mm wide ..... **L. prodigiosum**
6: Inflorescence a compact (closed) dichasium with 8–10 flowers. Staminal filaments (0.6–)1.1–1.3 mm long, anthers 0.9–1.9(–2.8) mm long; ovary 1.5–2.5 mm long, 2–3.1 mm wide ... **L. ferrugineum var. ferrugineum**
5: Calyx inner surface with fine glandular hairs intermixed with stellate hairs. Ovary outer surface with small, brittle hairs only ..... **L. ferrugineum var. cordatum**

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References

Council of Heads of Australasian Herbaria (2024) Australian Plant Name Index. URL [accessed 2 January 2024].

Department of the Environment (2013) *Australia's bioregions (IBRA). IBRA7, Commonwealth of Australia*. URL [accessed 2 January 2024].

Guymer GP (2022). Byttneriaceae. In Laidlaw MJ (ed), *Census of the Queensland Flora and Fungi 2022*. Queensland Department of Environment, Science and Innovation, Queensland Government. URL [accessed 14 February 2024].

Harden GJ (1990) *Lasiopetalum*. In: Harden GJ ed. *Flora of New South Wales*. Volume 1. pp. 309–311. (New South Wales University Press: Kensington).

Leiper G, Glazebrook J, Cox D, Rathie K (2017) *Mangroves to Mountains*: *A Field Guide to Native Plants of South-east Queensland*. Second Edition. (Native Plants Qld: Brisbane).

PlantNET (2024) *The NSW Plant Information Network System*. Royal Botanic Gardens and Domain Trust, Sydney. URL [accessed 14 February 2024].

Shepherd KA, Wilkins CF (2018) Typification of *Lasiopetalum* and an interim key to the Western Australian species of the genus (Malvaceae: Byttnerioideae). *Nuytsia* 29: 181–192. DOI

VicFlora (2024) *Flora of Victoria, Royal Botanic Gardens Victoria*. URL [accessed 14 February 2024].

Western Australian Herbarium (1998–) *Florabase—the Western Australian Flora*. Department of Biodiversity, Conservation and Attractions. URL [accessed 2 January 2024].

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The first record of *Bulbophyllum* sect. *Monomeria* (Orchidaceae) from Indonesia

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Abstract

Bulbophyllum crabro (E.C.Parish & Rchb.f.) J.J.Verm., Schuit. & de Vogel is recorded from Sumatra, which is the first record of this species from Indonesia. This is also the first record of *Bulbophyllum* section *Monomeria* (Lindl.) J.J.Verm., Schuit. & de Vogel outside continental Asia. A detailed description, a map, discussion, and colour photographs are provided.

Introduction

The northern part of the Gayo Plateau, northern Sumatra, is botanically one of the most under-sampled areas on the island. Eight species and one variety of orchid published since the year 2000 are from this area. All are, as far as now known, endemic to the northern part of the Gayo Plateau. These are *Bulbophyllum acehense* Metusala (Metusala 2020), *B. antoi* Cavestro (Cavestro 2020a), *B. wibowoajii* Jenny & R.Amsler (Jenny & Amsler 2020a, 2020b), *Dendrobium bandii* Cavestro (Cavestro 2020b), *D. gayoense* Handoyo, Cootes & Yudistira (Handoyo et al. 2020), *D. kruiense* subsp. *alboflavum* Yudistira, Romiyadi & Cootes (Yudistira et al. 2020), *Paphiopedilum bungebelangi* Metusala, *P. lunatum* Metusala (Metusala 2017), and *P. rohmanii* Cavestro & Gruss (Cavestro & Gruss 2020).

One remarkable new record from this area concerns a distinctive species of *Bulbophyllum* Thouars, a genus that consists of more than 2000 species (Vermeulen et al. 2014, Vermeulen et al. 2018). The species is *Bulbophyllum crabro* (C.S.P.Parish & Rchb.f.) J.J.Verm., Schuit. & de Vogel, which was previously known from mainland Asia, from Nepal and North-East India to Vietnam, and south to southern Thailand (Seidenfaden 1986) and Peninsular Malaysia (Abdullah 2007). It is a member of section *Monomeria* (Lindl.) J.J.Verm., Schuit. & de Vogel (Vermeulen et al. 2014). This new record also represents the first country record for Indonesia of a member of sect. *Monomeria*. A detailed description of *B. crabro* is provided below, to allow comparison between Sumatran material and that from continental Asia, together with some notes on sect. *Monomeria*.

Taxonomic Treatment

Bulbophyllum crabro (C.S.P.Parish & Rchb.f.) J.J.Verm., Schuit. & de Vogel, *Phytotaxa* 166: 106 (2014). Fig. 1.

Wendy A. Mustaqim et al. (2024) The first record of *Bulbophyllum* sect. *Monomeria* (Orchidaceae) from Indonesia. *Telopea* 27: 47–51. doi:10.7751/telopea17950

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Fig. 1. Morphology of *Bulbophyllum crabro* from the northern part of the Gayo Plateau. A: living plant. B: inflorescence. C: flower. D: flower, lateral view. E: Flower, front view. F: sepals. G: petals. H: column and labellum, lateral view (anther cap and pollinia missing). I: labellum and column, seen from above (anther cap and pollinia missing). J: column, showing stigma and anther cap (ac). Scales: A = 2 cm; B = 1 cm; C, D, F = 5 mm; E = 4 mm; G, H = 1 mm; I, J: 2 mm. Photographs by Wendy A. Mustaqim.

Basionym: *Monomeria crabro* C.S.P.Parish & Rchb.f., *Trans. Linn. Soc. London* 30: 143 (1874). *Type*: BURMA [Myanmar], near Taok, February 1871, *Parish 312* (lectotype, designated by Clayton (2017): W-RCHB; isolectotype: K [K000891011]).

Heterotypic synonyms: *Monomeria barbata* Lindl., *Gen. Sp. Orchid. Pl.*: 61 (1830). *Epicranthes barbata* (Lindl.) Rchb.f. in W.G. Walpers, *Ann. Bot. Syst.* 6: 265 (1861). *Type*: NEPAL, Toka, October 1821, *Wallich 1978* (lectotype, designated by Shankar (2021): K [K000974273]; isolectotype BM [BM000525277], G [G00434759], K-LINDL [K000974243], K-WALL [K001114839], W-RCHB).

Bulbophyllum monomeria J.J.Verm., *Gen. Orchid.* 6: 33 (2014), *nom. inval.*

Bulbophyllum barbatum auct. non Barb. Rodr., *Gen. Sp. Orchid.* 2: 119 (1882).

Bulbophyllum barbatum auct. non P.Royen, *Alpine Fl. New Guinea* 2: 211 (1979), *nom. illeg.*

Creeping rhizomatous epiphytic herb. *Rhizome* c. 5–7 mm diam., roots hairy 1–1.5 mm diam, mainly arising near the pseudobulb base, also some from the free part of the rhizome. *Pseudobulbs* 1.0–2.8 cm distant, ovoid, 3.3–3.6 × 2.4–2.7 cm, 1-leaved, green, eventually turning silvery grey and long persisting, longitudinally wrinkled when dry. *Leaves* petiolate, glabrous; plain green above, whitish below; *petiole* terete, 1.8–4.8 cm long; lamina oblong, 9.3–22 × 1.7–3.3 cm; apex slightly decurved, acute, shallowly retuse. *Inflorescence* from the base of the pseudobulb, a lax raceme, *c.* 34 cm long, 7-flowered, apical part with a few abortive flowers; peduncle 21.5 cm long, with 7 peduncle scales, including two marcescent basal ones, the largest 1.7 cm long, tubular in basal 9 mm; rachis 14.5 cm long, slightly pruinose, glabrous. *Floral bracts* c. 8.5–13 × 4.5–6 mm; apex acute, incurved and sheathing the pedicels, glabrous. *Pedicel* with *ovary* 19.5–23 mm long, slightly pruinose mainly on the ovary; ovary c. 3.5–4.5 mm long, ribbed. *Dorsal sepal* slightly hooded, ovate-triangular, glabrous, veins c. 5, apex acuminate, glabrous, outside slightly pruinose, 10.5–11 × 5.7–6 mm, base broadly attached. *Lateral sepals* slightly falcate, attached to the apical part of the column foot, c. 5.5 mm from the base of the column; 14–16 × 7.5–9 mm; outside glabrous, apex shortly acuminate, recurved, inner surface papillose except the apical part and around the margins. *Petals* strongly oblique, decurrent on the column-foot, ovate, 2–2.25 mm long, c. 6.5 mm wide at the base, margins fimbriate except for the decurrent part, with some of the projections branching, apex obtuse, shortly apiculate, surface glabrous; 1-veined. *Labellum* 3-lobed, glabrous, 8.0–8.5 × 4.2–4.5 mm; side-lobes basal, slender, hook-like, c. 3 mm long, acuminate, slightly curved outwards; mid-lobe ligulate-oblong, apical part reflexed from just below the middle, with entire margins, apex rounded, shallowly retuse, basal callus of two sharp, raised keels with a nectar-bearing groove in between and terminating about halfway along the reflexed apical part. *Column* 4.5–4.8 mm long (including the stelidia), stelidia triangular, 1 mm long, acute; upper side entire, lower side with a broad and rounded thick wing. *Anther* hooded, c. 1.2 × 1.5 mm, glabrous. *Pollinia* not seen. *Stigma* about 5-angular, 2 × 2.5 mm. *Fruit* not seen.

Phenology: Flowering October–February in continental Asia; in Sumatra flowering observed in July; fruiting time unknown.

Distribution: Nepal, North-East India, Myanmar, China, Vietnam, Thailand, Peninsular Malaysia, Indonesia (Sumatra). The distribution in Sumatra is shown in Fig. 2.

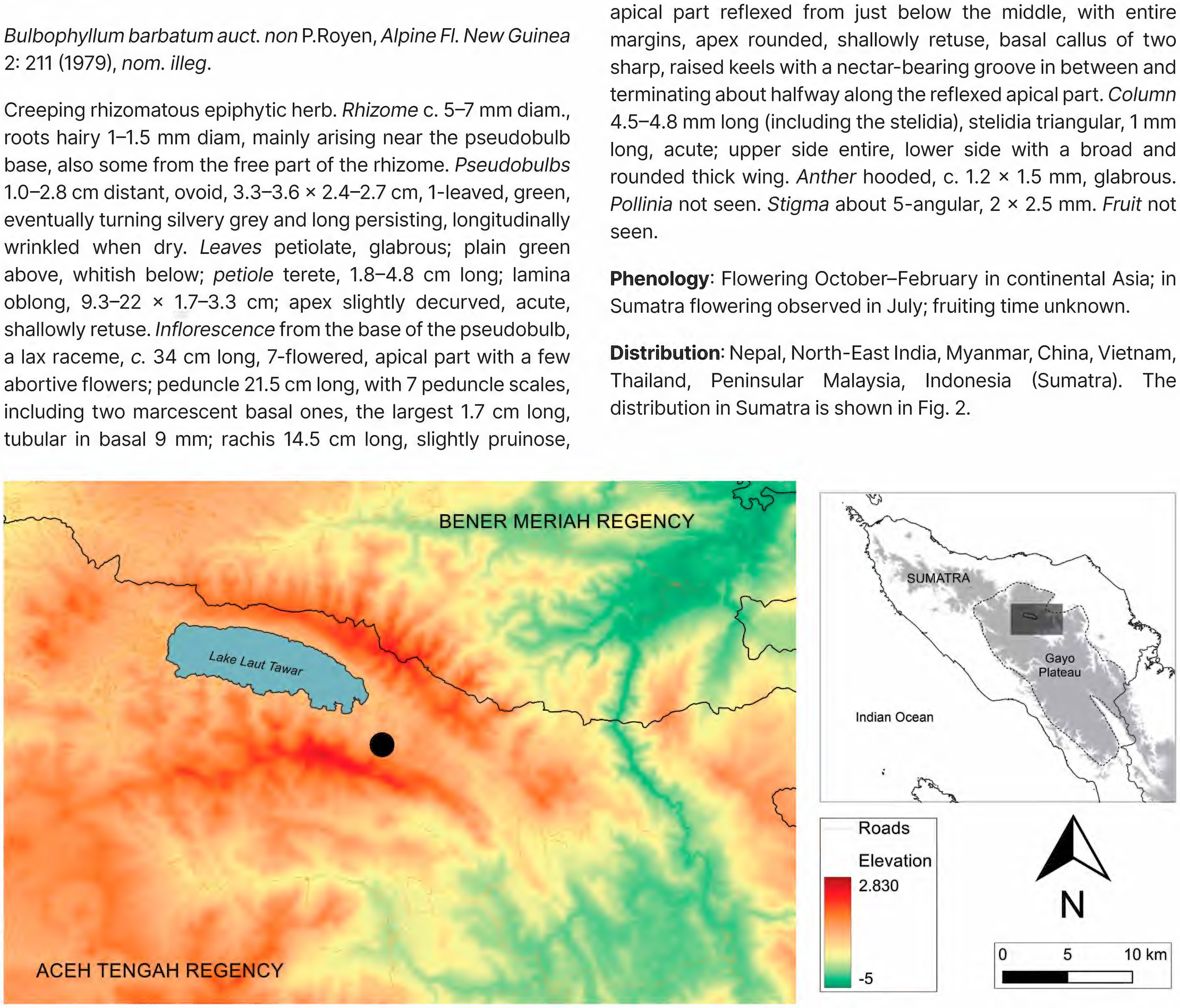

Fig. 2. Geographic distribution of *Bulbophyllum crabro* in the northern part of the Gayo Plateau, Sumatra, Indonesia (●). Map prepared using QGIS (QGIS Development Team 2023).

Habitat and ecology: This species can be epiphytic or lithophytic (Chen & Vermeulen 2009, Shankar 2021). The specimen from the northern Gayo Plateau was collected from plants creeping on the trunks of trees growing on limestone rock at an elevation of around 1720 m asl. It is the only known population of the species in Sumatra, with less than ten plants seen.

Notes: *Bulbophyllum crabro* was first described as *Monomeria crabro* from Myanmar in 1873 by Parish and Reichenbach f. (Parish's original watercolour painting is shown in Clayton 2017). It had long been considered a synonym of *Monomeria barbata* Lindl. (1830) but the specific epithet had to be resurrected when the species was transferred to *Bulbophyllum*, as the name *B. barbatum* was already in use. It should be noted that Shankar (2021) superfluously lectotypified *B. crabro*, as this had already been done by Clayton (2017).

The genus *Monomeria* Lindl. (Lindley 1830) was initially considered distinct from *Bulbophyllum* because it was believed that it lacked petals; this was later found to be incorrect (Reichenbach f. 1874) but the genus was maintained because of the presence of a stipe carrying the pollinia. However, this character state occurs elsewhere in *Bulbophyllum* (e.g., in *B. cornutum* (Blume) Rchb.f.), and molecular studies have confirmed that *Monomeria* is nested in *Bulbophyllum* (Li et al. 2016). The name *Monomeria* refers to the single globose body formed by the four pollinia.

According to Vermeulen (2014), *B.* sect. *Monomeria* is characterised by having a creeping rhizome; 1-leaved pseudobulbs longitudinally wrinkled with age; an elongate, racemose inflorescence, with the basal node of the pedicel at the base of the floral bract; flowers with a long column-foot, to which the sepals are attached in the apical half; 1-veined, ciliate [to erose-fimbriate] petals; a mobile and auriculate labellum; stelidia with winged upper margin; pollinia attached to a stipe. Two other species are currently included in sect. *Monomeria*: *B. dichromum* Rolfe from Vietnam and *B. fengianum* (Ormerod) J.J.Verm., Schuit. & de Vogel from China. From the former, *B. crabro* differs in having petals broader than long (vs. petals longer than broad) and spotted sepals (vs. unspotted or striped sepals); from *B. fengianum*, *B. crabro* differs in having twisted sepals, so that the abaxial surface is turned uppermost (vs. untwisted sepals).

It should be noted that five *Bulbophyllum* species that have been included in the genus *Monomeria* are no longer considered to belong to sect. *Monomeria*, viz.: *B. digitatum* J.J.Sm. (sect. *Gongorodes*); *B. gymnopus* Hook.f. (sect. *Altisceptrum*), *B. longipes* Rchb.f. (sect. *Henosis*), *B. kingii* Hook.f. (sect. *Acrochaene*), and *B. rimannii* (Rchb.f.) J.J.Verm., Schuit. & de Vogel (sect. *Ione*).

Outside Sumatra, *B. crabro* has a wide distribution in tropical continental Asia, including Peninsular Malaysia. There are other orchids showing this distribution pattern, for example, *Cyrtosia lindleyana* Hook.f. & Thomson (Comber 2001).

The record of *B. crabro* from the northern Gayo Plateau highlights an important point in the phytogeography of this mountain complex. Located in the northern part of Sumatra, the flora of this region shows notable similarities to that of mainland SE Asia. Many continental taxa have populations there. Some non-orchid examples of species from the northern Gayo Plateau having mainland SE Asia or beyond as their center of distribution include *Pinus merkusii* Jungh. & de Vriese (Pinaceae; de Laubenfels 1988a, Mustaqim 2020), *Rhodoleia championii* Hook. (Hamamelidaceae; Vink 1957), *Acer laurinum* Hassk. (Sapindaceae; Adema et al. 1994), *Dacrydium medium* de Laub. (Podocarpaceae; De Laubenfels 1988b), and many others (De Wilde and Duyfjes 2001).

Specimen examined. INDONESIA. Aceh Province, Aceh Tengah Regency, Bintang Subdistrict, near Wihlah Setie Village (4°33'09.8"N, 97°00'18.4"E), 1720 m a.s.l., *WA Mustaqim et al.* 2753, 23 July 2023 (LGS).

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References

Abdullah E (2007) The discovery of the genus *Monomeria* Lindl. (Orchidaceae) in Cameron Highlands: a new record for Malaysia. *Folia Malaysiana* 8: 41–49.

Adema F, Leenhouts PW, van Welzen PC (1994) Sapindaceae. *Flora Malesiana* ser. 1, 11(3): 419–768.

Cavestro W (2020a) *Bulbophyllum antoi* Cavestro, a new species from Aceh Province, North Sumatra, Indonesia. *Die Orchidee* 6(19): 163–169.

Cavestro W (2020b) *Dendrobium bandii* Cavestro - a new species from Aceh Province, North Sumatra, Indonesia. *Die Orchidee* 6(20): 170–176.

Cavestro W, Gruss O (2020) A new *Paphiopedilum* in the section *Barbata* (Kraenzlin) V.A. Albert & Börge Pett from northern Sumatra, Indonesia. *Orchideen Journal* 5(3): 6–8.

Chen X, Vermeulen JJ (2009) *Monomeria* Lindl. In: Wu Z, Raven PH, Hong D (eds.), *Flora of China. Volume 25: Orchidaceae*. (Missouri Botanical Garden Press, Missouri)

Clayton D (2017) *Charles Parish—Plant Hunter and Botanical Artist in Burma*. (The Ray Society, London, in association with Royal Botanic Gardens, Kew)

Comber J (2001) *Orchids of Sumatra*. (Natural History Publications (Borneo), Kota Kinabalu)

De Laubenfels DJ (1988b) Podocarpaceae. *Flora Malesiana* ser. 1, 10(3): 351–419.

De Wilde WJJO, Duyfjes BEE (1994) Brief history of the botanical exploration in the Gunung Leuser Natural Park and vicinity, North Sumatra. *Flora Malesiana Bulletin* 11(4): 253–291.

De Wilde WJJO, Duyfjes BEE (2001) On the special botanical character of the Leuser Park and vicinity, with emphasis on the high mountain blang vegetation of northern Sumatra. *Flora Malesiana Bulletin* 12(7/8): 377–391.

Handoyo F, Cootes J, Yudistira YR (2020) *Dendrobium gayoense* (Section *Calcarifera*, Orchidaceae), a new species from Aceh, Sumatra, Indonesia. *Die Orchidee* 6(13): 99–105.

Jenny R, Amsler R (2020a) *Bulbophyllum wibawoajii* Jenny et R. Amsler – a new species from Sumatra. *Die Orchidee* 6(22): 191–195.

Jenny R, Amsler R (2020b) Correction to *Bulbophyllum wibawoajii* Jenny et R. Amsler, a new species from Sumatra. *Die Orchidee* 6(23): 196–198.

Li MH, Zhang GQ, Lan SR, Liu ZJ, China Phylogeny Consortium (2016) A molecular phylogeny of Chinese orchids. *Journal of Systematics and Evolution* 54(4): 349–362.

Lindley J (1830) *The Genera and Species of Orchidaceous Plants*. (Ridgways, London)

Metusala D (2017) Two new species of *Paphiopedilum* (Orchidaceae: Cypripedioideae) Section *Barbata* from Sumatra, Indonesia. *Edinburgh Journal of Botany* 74(1): 1–10. DOI

Metusala D (2020) *Bulbophyllum acehense* (Orchidaceae), a new species of section *Beccariana* from Aceh, Sumatra, Indonesia. *Jurnal Biologi Tropis* 20(1): 111–115. DOI

Mustaqim WA (2021) *Pinus merkusii* Jungh. & de Vriese Pinaceae. In: Franco F (eds) *Ethnobotany of the Mountain Regions of Southeast Asia*. Ethnobotany of Mountain Regions. (Springer, Cham). DOI

QGIS Development Team (2023) QGIS Geographic Information System. Open Source Geospatial Foundation Project. URL (accessed 28 May 2023).

Ormerod P (2011) Orchidaceous additions to the flora of China. *Taiwania* 56(1): 42–49.

Reichenbach, HG (1874) Enumeration of the orchids collected by the Rev. E.C. Parish in the neighbourhood of Moulmein, with descriptions of the new species. *Transactions of the Linnean Society of London* 30: 133–155.

Seidenfaden G (1986) Orchid Genera in Thailand XIII. Thirty-three epidendroid genera. *Opera Botanica* 89: 1–216.

Seidenfaden G, Wood JJ (1992) *The Orchids of Peninsular Malaysia and Singapore*. (Olsen & Olsen, Fredenburg)

Shankar U (2021) Lectotypification and recollection of *Bulbophyllum crabro* in Meghalaya after 125 years. *Rheedea* 31(3): 211–217.

Stevens PF (2001-onwards) Angiosperm Phylogeny Website. Version 14, July 2017. URL (accessed 28 May 2023)

Van Welzen PC (2017) Cyclopaedia of Malesian Collectors. URL (accessed 28.05.2023)

Vermeulen, JJ (2014) Artificial key to the Asian sections of *Bulbophyllum*. In: Pridgeon AM, Cribb PJ, Chase MW, Rasmussen FN (eds.), *Genera Orchidacearum, Volume 6 Epidendroideae (Part three)*. (Oxford University Press, Oxford)

Vermeulen JJ, Schuiteman A, De Vogel EF (2014) Nomenclatural changes in *Bulbophyllum* (Orchidaceae; Epidendroideae). *Phytotaxa* 166 (2): 101–113.

Vermeulen JJ, Schuiteman A, De Vogel EF (2018) New taxa in *Bulbophyllum* (Orchidaceae: Epidendroideae: Malaxideae) from New Guinea, lifting a mega-genus over the 2000-species mark. *Malesian Orchid Journal* 21: 31–68.

Vink W (1957) Hamamelidaceae. *Flora Malesiana* ser. 1, 5(3): 363–379.

Yudistira YR, Romiyadi, Cootes J (2020) *Dendrobium kruiense* subspec. *alboflavum*, a new subspecies from section *Calcarifera* (Orchidaceae, Dendrobiinae), from Aceh, Sumatra, Indonesia. *Die Orchidee* 6(12): 92–98.

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Grevillea kulikup (Proteaceae: Grevilleoideae: Hakeinae) a rare new species from south-west Western Australia

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Abstract

Grevillea kulikup Olde is described along with details of habitat, associated flora and conservation status. The recently discovered new species is known from a single population of less than 20 individuals. The most recent key to related species is modified.

Introduction

A new species is described here to recognise a morphologically distinct population from its current designation as *Grevillea acropogon* Makinson. *Grevillea acropogon* is a threatened species in southwestern Australia that was known from only a single population near Lake Unicup (Makinson 2000; Department of Environment and Conservation 2010). A supposed additional population was discovered some 50 km north on a private property near Kulikup in 2001 by local resident Anne Staniforth-Smith. From 2013, the population was monitored by local volunteer M. Sowry, who reported the number of plants in the population to the Department of Biodiversity, Conservation and Attractions (DBCA). In 2015, local discussions began on the morphological differences between the two populations and their possible importance. During sampling for a recent student project aiming to use population genomic data to inform the conservation management of these two populations, it was noted again that they were not morphologically uniform. The genetic analyses were thus adapted to assess the evolutionary relationship of these two populations relative to other closely related species. These molecular analyses confirmed that the two populations are not conspecific and will be published in a forthcoming paper following completion of the student project. To expedite conservation actions, here we document the morphological variation and describe the Kulikup population as a new species, *Grevillea kulikup*. The species is morphologically similar to *G. acropogon* and *G. ripicola* A.S.George and thus is placed tentatively in the Thelemanniana Group (Group 14 *sensu* Olde & Marriott 1994), the monophyly of which has been called into question by Hevroy (2016). Four species, additional to those recognised in the *Flora of Australia* treatment (Makinson 2000), were recently added by Olde & Keighery (2022). The most recent key to species (Olde & Keighery 2022) is modified below.

Olde PM, Binks RM and Wardrop C (2024) *Grevillea kulikup* (Proteaceae: Grevilleoideae: Hakeinae) a rare new species from south-west Western Australia. *Telopea* 27: 53–57. doi:10.7751/telopea17794

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Amended key to the *Grevillea thelemanniana* Group

From Olde & Keighery (2022: 335–337)

3: Pistils 20–25 mm long; leaf rachis angularly refracted at all nodes; outer surface of perianth dull *in vivo*; leaf lobes 0.8–1.1 mm wide, linear, the under-surface enclosed by margins or not when dry, sericeous or villous in the grooves beside the midvein; simple leaves never present; intramarginal veins not evident on leaf upper surface..... 3A

3A Pistils 20–22 mm long; leaves and branchlets glabrous or with appressed hairs (near Lake Unicup)..... ***G. acropogon***

3A: Pistils 24–25 mm long; leaves and branchlets villous (Kulikup) ..... ***G. kulikup***

Taxonomy

Grevillea kulikup Olde, **sp. nov.**

Type: Western Australia: Kulikup (precise locality details withheld for conservation reasons), *P.M. Olde* 23/27, 9 September 2023 (holo: PERTH; iso: AD, BRI, CANB, K, MEL, NE, NSW, P).

Spreading, grey-green, seed-obligate shrubs 0.5–1 m high, 2–3 m wide. *Branchlets* reddish to yellow, subterete, openly and consistently villous with irregularly oriented biramous hairs up to 2 mm long. *New growth* loosely villous. *Leaves* 1–2 cm long, 2.5–3.5 cm wide, dorsiventral, spreading, subsessile, divided, divaricately complex, tri-pinnatisect or partly so, with 3–7 primary lobes, the lobes all similar, linear; *primary lateral lobes* 12–15 mm long, 20–30 mm wide, the rachis c. 1 mm *wide,* spreading to patent, usually in subopposite pairs, the proximal pair always with tertiary division; *secondary lateral lobes* 15 mm long, 15 mm wide, with a further trisected division, opposite or not, usually straight; *tertiary lateral lobes* c. 7 mm long; *terminal lobe* 10–13 mm long; *ultimate leaf lobes* 16–30 per leaf, 7–15(–17) mm long, *c*. 1 mm wide; *basal rachis node* 5–7 mm long; *leaf base* linear; *margins* loosely and smoothly revolute; *lobe apices* scarcely pungent; *adaxial surface* loosely villous to hispid, dull, the midvein obscure to evident and slightly raised; *abaxial surface* mostly or wholly enclosed except for midveins, sometimes lamina narrowly exposed beside the midvein and then villous; *texture* pliably coriaceous. *Conflorescence* decurved, subterminal, shortly and broadly secund, 18–24-flowered, usually simple, occasionally 3-branched, acropetal; *buds* ovoid, pedunculate; *peduncles c*. 10 mm long, wiry, hispid; *rachis* 15–20 mm long, glabrous, sometimes a few appressed hairs at base; *common bracts* 0.7 mm long, 0.5 mm wide, ovate, glabrous-ciliate, sometimes a few spreading long hairs scattered on the abaxial surface. *Flower colour* red except the ovary and the style-end green, the nectary and anthers white. *Flowers* zygomorphic, inodorous, acroscopic; *pedicels* 4 mm long, 2 mm wide, glabrous, dilated gradually at the apex; *torus* 0.8–1 mm wide, oblique, cupuliform; *nectary* broadly u-shaped, scarcely evident above the toral rim, the margin thick along the sides, flattened and sub-linguiform at centre-face. *Pistils* 24–25 mm long, glabrous; *gynophore* 3 mm long, slightly incurved, not compressed, inserted towards the dorsal side of the torus; *ovary* 1.5 mm long, 1.2 mm wide at base, triangular, smooth, the base not ridged, retrorse; *style-end* gradually expanded; *pollen-presenter* 1.3 mm long, 0.8 mm wide, oblique, oblong with rounded corners, the surface with a slight central boss surrounded by a narrow flange c. 0.2 mm wide. *Perianth* 9 mm long, 1.5 mm wide, narrowly ovoid, subregular in late bud, becoming quickly zygomorphic pre-anthesis, the tube coherent except along the dorsal suture, outside glabrous, inside subglabrous in the basal 4 mm, densely bearded at the curve, the perianth falling as a coherent unit after anthesis; *limb* 0.8 mm long, 1.3 mm wide, depressed spheroidal, sparsely sericeous, revolute at anthesis; *tepals* attached inside the toral rim, markedly papillose on the margins; *tepal-limbs* with spreading rusty hairs at the tip, separating and rolling back after anthesis. *Follicles* 15 mm long, 5 mm wide, 5 mm deep, narrowly obovoid, truncate at base; *style* persistent, emergent from the acute apex; *exocarp* smooth, soon cracking; *mesocarp* crustaceous; *endocarp* smooth, concolorous; *pericarp c*. 03 mm across at suture. *Seeds* not seen. (Figures 1, 2A–E)

Diagnostic characters: Similar to *G. acropogon* Makinson (Figs 2F–H, 3) but differing in its branchlets and leaves with a persistent, loosely villous indumentum (versus glabrous or with appressed hairs), the division of each leaf more complex, (widest leaves with c. 30 ultimate lobes versus 16) and with a higher proportion of lobes with tertiary development (all or most versus none or occasional), the proximal lobes always with tertiary division (versus occasional or tertiary division absent), the basal leaf rachis node longer (5–7 mm versus 3–5 mm long); its pistils slightly longer (24–25 mm long versus 20–22 mm long), the ovary with base retrorse (versus obliquely truncate); the nectary obscure (scarcely rising above the toral rim) (versus prominent and rising c. 0.2 mm above the toral rim).

Distribution: Western Australia. Occurs in the Boyup Brook Local Government Area where it is known only from a single population at the type locality.

Phenology: Flowers from late winter to spring.

Habitat and ecology: Shrub in open seasonally damp woodland heath dominated by *Eucalyptus wandoo* with *Banksia nivea* Labill. subsp. *nivea*, *Hakea lissocarpha* R.Br., *Hibbertia depilipes* K.R.Thiele, *Leptospermum erubescens* Schauer, *Xanthorrhoea preissii* Endl. and *Loxocarya striata* (F.Muell.) B.G.Briggs & L.A.S.Johnson. Soils are grey sandy loam with laterite.

Conservation status: Despite extensive survey, the species is only known from a single population of less than 20 plants and is therefore in urgent need of conservation assessment.

Etymology: The epithet *kulikup* is a place name of Aboriginal Noongar origin but its meaning is uncertain. The name was first applied to a nearby railway siding but was later gazetted for the townsite and surrounding 283 sq km area. The epithet is used here as an indeclinable noun in apposition.

Figure 1. *Grevillea kulikup*. A. Habit and habitat. B, C. Leaves and flowers. Photos: A, B: P. Olde; C: A. Crawford.

Figure 2. A–E: *Grevillea kulikup*, detail from holotype and isotypes. A. Habit of branchlet with inflorescence. B. Leaf. C. Trifid leaf apex showing indumentum. D. Carpel. E. Fruit. Voucher: *P.M. Olde 23/27* (NSW, P, PERTH). F–H: *Grevillea acropogon*. F. Habit of branchlet with inflorescence. G. Leaf. H. Carpel. Voucher: *P.M. Olde 01/151 & N. Marriott* (NSW 535102). Illustration by Catherine Wardrop.

Figure 3. Flowers and leaves of *Grevillea acropogon*. Photo: K. Stokes.

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References

Department of Environment and Conservation (2010) *Grevillea acropogon* Interim Recovery Plan 2010–2015. Interim Recovery Plan No. 321. (Department of Environment and Conservation, Western Australia). URL

Department of Environment (2018) Conservation advice: *Grevillea acropogon*. (Threatened Species Scientific Committee: Canberra, Australian Capital Territory). URL

Hevroy TH (2016) Molecular phylogeny and population genetics of the *Grevillea thelemanniana* group (Proteaceae). (Thesis, Doctor of Philosophy, UWA School of Plant Biology). URL

Makinson RO (2000) *Proteaceae 2,* Grevillea. *Flora of Australia Volume 17A*. (CSIRO Publishing: Melbourne) URL

Olde PM, Keighery GJ (2022) New species and taxonomic changes in the *Grevillea thelemanniana* Group (Proteaceae: Grevilleoideae: Hakeinae) from south-west Western Australia. *Telopea* 25: 331–352. DOI

Olde PM, Marriott NR (1994) *The Grevillea Book. Vol. 1.* (Kangaroo Press: Kenthurst, New South Wales)

Wikipedia (2023) Kulikup, Western Australia (accessed 12 October 2023) URL

BOTANIC GARDENS OF SYDNEY

Telopea

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The identity of *Eucalyptus virgata* Sieb. ex Spreng.

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Abstract

Eucalyptus virgata was validly published in 1827, but the name has not been in common usage for several decades. Its identity has been uncertain because the type lacks mature flower buds and fruits, and there was no description provided for bark or habit. The current availability of numerous images of the type has allowed a careful examination of salient characters, and *E. virgata* is thought to be conspecific with *E. oreades* R.T.Baker, or possibly *E. dendromorpha* (Blakely) L.A.S.Johnson & Blaxell. Morphological comparisons are made with other related species that have been attributed to *E. virgata* over the years.

Introduction

Eucalyptus virgata Sieb. ex Spreng. was validly published by Kurt Sprengel in 1827, based on a collection by Franz Sieber made in 1823. Sieber is well known by Australian botanists for the plant collections he made in the greater Sydney region. He collected specimens of 645 species of angiosperm (Dietrich 1881), each well pressed and usually comprising numerous duplicates. Sieber was one of the first botanists to assign a unique number to each gathering before distribution of the duplicates. Consequently, it is easy to match up duplicates now occurring in different herbaria. The species list provided by Dietrich (1881) shows that his numbers were not assigned in a chronological sequence. Sieber evidently sorted his collection into families and genera then assigned numbers accordingly. For example, numbers 436 to 466 are all *Acacia* spp.; numbers 467–480 are all *Eucalyptus* spp. In no case did Sieber indicate a collecting locality, beyond "Nov. Holl", but it is known that he ranged widely along the coastal areas north and south of Sydney and also in the Blue Mountains (Ducker 1990).

Confusion has surrounded the name *Eucalyptus virgata* for many years. Its identity has been uncertain because the type lacks mature flower buds and fruits, and there was no bark or habit description provided. Candolle (1828) had only Sieber's collection (Sieb! pl. exs. nov.-holl. n. 467) to work with, and he provided the final unadulterated description of *E. virgata*. Bentham (1867) accepted *E. virgata*, and he cited Sieber's collection, but his description is almost entirely based on specimens of a tree with dark fibrous bark on the trunk and smooth upper branches, with the common name Silvertop ash.

Mueller (1879) apparently agreed with Bentham's taxonomic interpretation of *Eucalyptus virgata*, but he took the extraordinary step of replacing *E. virgata* with his own name, *E. sieberiana*, because "the original adjective 'virgata' is very misleading". As he ignored

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the rule of priority, *E. sieberiana* F.Muell. is an illegitimate name. That fact was recognised by Johnson (1962), who coined the name *E. sieberi* L.A.S.Johnson for the Silvertop ash.

J.H. Maiden studied all species of *Eucalyptus* as part of his 'Critical Revision of the genus Eucalyptus'. In the first part of that work, Maiden (1909) considered that *E. virgata* and *E. stricta* Sieb. ex Spreng. were synonymous. He stated that "Typical *E. virgata*, Sieb., is usually a tall shrub, as its name denotes". Maiden had no way of knowing that *E. virgata* was a tall shrub because Sieber did not provide that information, but the statement shows that Maiden was heavily influenced by the specific epithet in deciding the identity of *E. virgata*, and he seemingly discounted any tree-form species as a candidate for *E. virgata*. Later, Maiden (1920) decided that *E. virgata* was synonymous with the mallee species *E. luehmanniana* F.Muell. Blakely (1934) followed Maiden's more recent opinion by accepting *E. virgata* and placing *E. luehmanniana* as a synonym of it.

Johnson (1962) stated that he had seen an isotype of *Eucalyptus virgata* at NSW, and that it "undoubtedly represents the occasional hybrids between *E. luehmanniana* F.Muell. and either *E. obtusiflora* DC. or *E. stricta* Sieb. ex Spreng. *s. str.*". He provided no evidence at all that the *E. virgata* type is a hybrid. Hybrids between the mentioned species are rare, if they exist at all: no specimen of *E. luehmanniana* × *E. stricta* is recorded on AVH (2024). Only one specimen of *E. luehmanniana* × *E. obstans* (replacement name for *E. obtusiflora auct. non* DC.) is recorded on AVH (2024), i.e. *Coveny 16408 & Whalen* (BRI, NSW), and that specimen was determined by Johnson. The specimen has 7–13-flowered umbels, flattened peduncles and angular branchlets, and in my opinion, it lies within the range of variation exhibited by *E. luehmanniana*.

Pryor and Johnson (1971) echoed Johnson (1962) by stating that *Eucalyptus virgata* is a hybrid between *E. luehmanniana* and *E. obtusiflora*. Chippendale (1988), in the *Flora of Australia*, accepted the assertion of Pryor and Johnson (1971) and relegated *E. virgata* to one of many 'Presumed Hybrids' listed in an appendix.

Taxonomy

Eucalyptus virgata Sieb. ex Spreng., *Systema Vegetabilium* ed. 17, 4(2): 195 (1827); *E. sieberiana* F.Muell., *Eucalyptographia Decade* 2, 9th plate (1879), *nom. illeg.*; *E. virgata* Sieb. ex Spreng. var. *virgata*, H.Deane & Maiden, *Proceedings of the Linnean Society of New South Wales* 26(1): 124 (1901). **Type:** Nov. Holl., [June–December 1823], *F.W. Sieber 467* (lecto: BM 000799425, here designated; isolecto: BM 000799424, BR 522977, G 00227792, G 00227791, G 00227790, GH 00069087, FI 011468, H 1386839, HAL 89646, K 000279932, M 0137422, MEL 567382, MEL 1616396, NSW 26896, NSW 325435, S 07-11590, W 34408, W 178167, W 0047648, W 0047649).

I have examined images of 19 duplicates of the type of *Eucalyptus virgata*, held at 12 herbaria (JSTOR 2024). All comprise leafy branches bearing immature flower buds. These clearly all belong to the same taxon, and because the flower buds are consistent in their level of maturity and the leaves are of very similar size and shape, it is probable that all duplicates originated from the same tree. There are 2 additional duplicates at NSW (AVH 2024).

I believe that the type material of *Eucalyptus virgata* belongs to the species currently known as *E. oreades* R.T.Baker (Blue Mountains Ash), because of shared features such as 7-flowered inflorescences with a flattened peduncle, the conical, obtuse operculum and the falcate leaves with acutely angled lateral veins and many raised oil glands, but *E. dendromorpha* is also a possibility. The morphological features of *E. virgata* (type material) are compared below with *E. oreades* and all other species ever linked to *E. virgata*, i.e. *E. sieberi, E. burgessiana, E. stricta*, *E. luehmanniana*, and *E. dendromorpha* (Table 1).

Table 1. A comparison of leaf, branchlet and flower bud characters for *Eucalyptus virgata*, *E. oreades*, *E. sieberi*, *E. luehmanniana*, *E. stricta*, *E. burgessiana* and *E. dendromorpha*. Leaf widths are derived from Slee *et al.* (2020). All other characters have been assessed from herbarium specimens and Research Grade iNaturalist observations.

Character	*E. virgata* (type)	*E. oreades*	*E. sieberi*	*E. luehmanniana*	*E. stricta*	*E. burgessiana*	*E. dendromorpha*
Buds per umbel	3–6	7	7–15	7–15	7	7	7
Peduncle shape	flattened	flattened	terete	flattened	terete	± terete	flattened
Bud shape (immature)	cylindrical	cylindrical to narrowly ellipsoidal	obovoid to clavate	diamond shaped	obovoid	obovoid to narrowly ellipsoidal	obovoid to clavate
Operculum shape	conical, obtuse, unribbed	conical, obtuse, unribbed	patelliform (shallow dome)	acuminate, longitudinally ribbed	hemispherical, umbonate, unribbed	hemispherical, umbonate, unribbed	conical or hemispherical, umbonate, unribbed
Branchlets shape	terete except at end of branchlet	terete except at end of branchlet	terete throughout	prominently square in cross-section	terete throughout	terete throughout	terete except at end of branchlet
Leaf width (mm)	11–27	10–32	12–38	20–45	6–16	13–25	10–25
Leaf shape	falcate	falcate	lanceolate to falcate	falcate	linear to lanceolate	narrow lanceolate to falcate	falcate

Fig. 1. Isolectotype of *Eucalyptus oreades* (K 000279930).

Fig. 2. Isolectotype of *Eucalyptus virgata* (M 0137422).

Eucalyptus sieberi differs from the type of *E. virgata* by the patelliform (shallow dome-like) operculum, the greater number of buds per umbel and the terete peduncles. *Eucalyptus luehmanniana* differs from the type of *E. virgata* by the prominently angular branchlets, the greater number of buds per umbel, and the beaked and ribbed operculum. *Eucalyptus stricta* differs from *E. virgata* by the narrower, non-falcate leaves and the terete peduncles. *Eucalyptus burgessiana* L.A.S.Johnson & Blaxell (syn: *E. obstans* L.A.S.Johnson & K.D.Hill, *E. obtusiflora* auct. non DC.) differs from *E. virgata* by the terete or almost terete peduncles, the hemispherical and umbonate operculum, and the branchlets terete throughout. *Eucalyptus dendromorpha* differs from *E. virgata* only by the broader obovoid buds.

Eucalyptus oreades matches the *E. virgata* type in all regards, viz. the flattened peduncles, the falcate leaves, the branchlets angular at the ends only, the conical unribbed operculum, and umbels with a maximum of 7 buds, but it is not possible to exclude the possibility that *E. virgata* = *E. dendromorpha*, which is very similar in most available characters.

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References

AVH (2024) The Australasian Virtual Herbarium. URL (Accessed 20 February 2024)

Bean AR (2009) Typification of some names in *Eucalyptus* (Myrtaceae), Part 1. *Telopea* 12: 309–319.

Bentham G (1867) *Eucalyptus*. In: *Flora Australiensis*. Volume 3. pp. 185–261. (L. Reeve and Co.: London)

Blakely WF (1934) *A key to the Eucalypts, with descriptions of 500 species and 138 varieties*. (Worker Trustees: Sydney)

Candolle AP de (1828) *Eucalyptus*. In: *Prodromus Systematis Naturalis Regni Vegetabilis*. Volume 3. pp. 216–222. (Treuttel and Wurtz: Paris)

Chippendale GM (1988) Myrtaceae - *Eucalyptus, Angophora*. *Flora of Australia*, Volume 19. (Australian Government Publishing Service: Canberra)

Deane H, Maiden JH (1898) Observations on the Eucalypts of New South Wales, part III. *Proceedings of the Linnean Society of New South Wales* 22: 704–720.

Deane H, Maiden JH (1901) Observations on the Eucalypts of New South Wales, part VIII. *Proceedings of the Linnean Society of New South Wales* 26: 122–144.

Dietrich FC (1881) Franz Wilhelm Sieber, ein Beitrag zur Geschichte der Botanik vor sechzig Jahren. *Jahrbuch des koniglichen Gartens des Museums zu Berlin* 1: 278–306.

Ducker SC (1990) Early Austrian influence on Australian botany. In: Short PS (ed.), *History of systematic botany in Australasia*. pp. 297–304. (Australian Systematic Botany Society Inc: Collingwood, Victoria)

Johnson LAS (1962) Studies in the taxonomy of *Eucalyptus*. *Contributions from the New South Wales National Herbarium* 3: 103–126.

JSTOR (2024) JSTOR Global Plants. URL (Accessed 16 February 2024)

Maiden JH (1909) XXVIII. *E. virgata*, Sieb. *Critical revision of the genus Eucalyptus*. Volume 1, pp. 273–284. (Gullick: Sydney)

Maiden JH (1920) XXVIII. *E. virgata* Sieber., *Critical revision of the genus Eucalyptus*. Volume 4, pp. 283–289. (Gullick: Sydney)

Pryor LD, Johnson LAS (1971) *A classification of the Eucalypts*. (The Australian National University: Canberra)

Slee AV, Brooker MIH, Duffy SM, West JG (2020) Euclid, Eucalypts of Australia. (edn 4). URL (Accessed 18 February 2024).

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Liverwort and hornwort collections of Heinar Streimann from Vanuatu

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Abstract

From the rich Vanuatu bryophyte collections of the late Heinar Streimann, 29 liverworts and one hornwort species were identified. One genus (*Schiffneriolejeunea*) and 16 species proved to be new records for the islands, 6 of them new to the whole Pacific realm.

Introduction

Vanuatu (formerly New Hebrides) is an archipelago consisting of 83 islands, with a total area of more than 12,000 km^2, and is part of the East Melanesian Islands hotspot. The Y-shaped archipelago extends in a length of 800 km from the 13th to the 20th latitude, south to the Tropic of Capricorn (see Fig. 1). Its nearest neighbours are the Santa Cruz Islands to the north, New Caledonia 400 km to the southwest, and the Fiji Islands about 800 km to the east (Munzinger 2009). The Vanuatu Islands are of Tertiary volcanic origin, now partly covered by Pleistocene and more recent coral limestone terraces, volcanic activity and island building continues to this day. The climate is wet tropical, receiving 4000 mm rain per year in the north to 2000 mm in the south. The precipitation is more or less seasonal with 3 months dry season in the north, to 6 months in the south. The mean annual temperature at sea level varies from 26°C in the north to 23°C in the south. Accordingly, the islands were covered by wet and mesic tropical forests, a great part of them already cut over, with the exception of smaller islands and higher mountains (Mueller-Dombois and Fosberg 1998).

Mitten (1868) published the first moss records and Stephani (1906–1917) published a good number of liverworts from the New Hebrides in his *Species Hepaticarum* and also in his publication *Hepaticae Australes* (Stephani 1914). Tixier (1973, 1974) published a further 50 liverwort species, from the collections of Royal Society Expedition in 1971. Even so, our knowledge on the bryophytes, especially on the liverworts of Vanuatu is very deficient. This is demonstrated by the fact that about half of the species in any unidentified collection prove to be new records for the islands. And if we compare this, for example, to the liverwort flora of New Caledonia, only 400 km away, the difference is even more apparent (Vitt 1991). Interestingly, the biota of the islands is more closely related to that of Fiji than it is to New Caledonia, which is only half the distance away (Chew 1975). These facts can be explained partly by their different geology, and partly by our more limited knowledge on the biota of Vanuatu.

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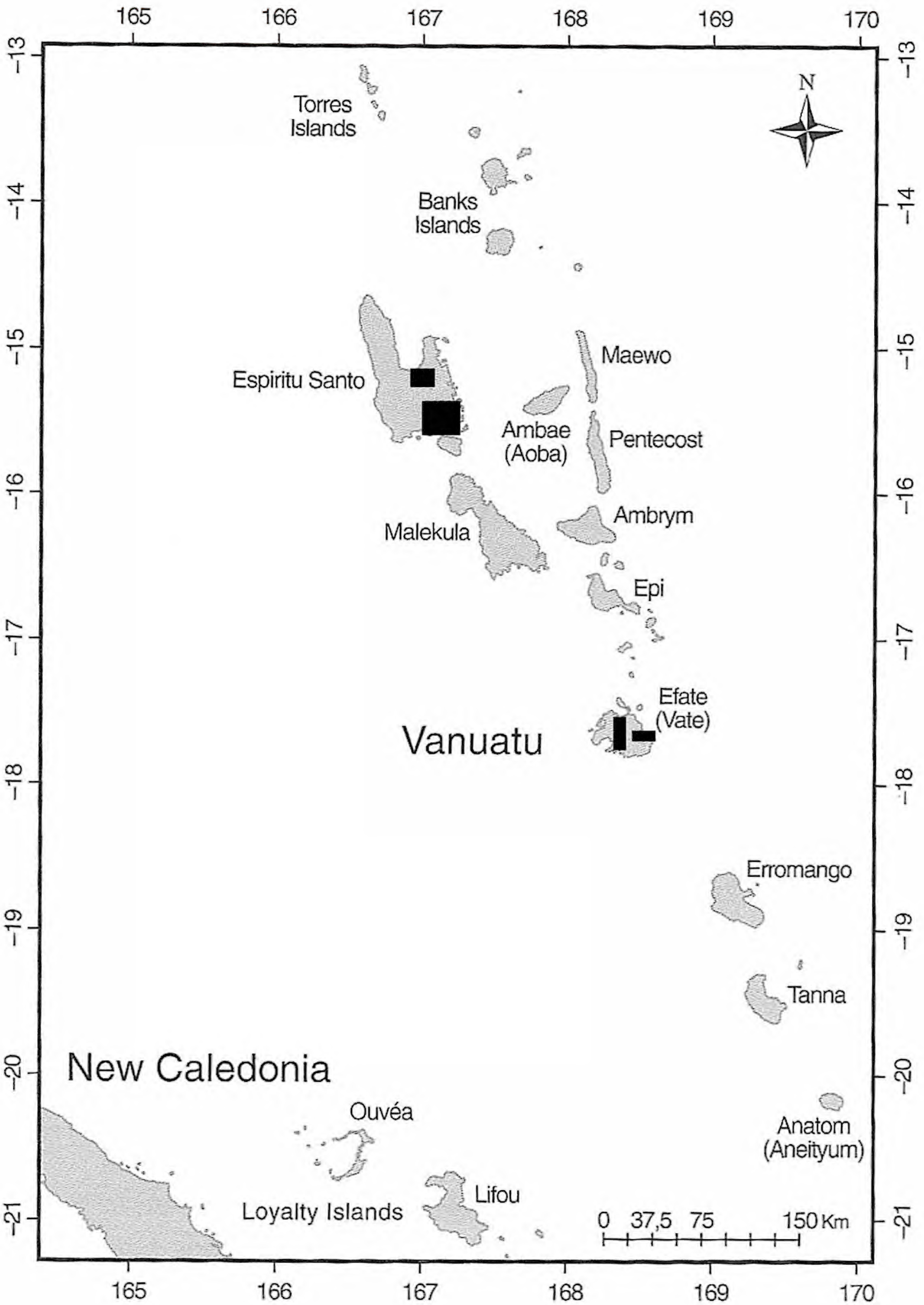


Fig.1. The collecting sites of Heinar Streimann on Vanuatu Islands (marked in black). Derived from the maps of Streimann and Reese (2001) and Munzinger (2009).

Heinar Streimann (1938–2001), was born in Estonia, then escaped to Germany, grew up and lived in Australia from 1950. He first worked in Papua New Guinea then became a well-known botanist as the curator of cryptogamic plants in the Australian National Botanic Gardens Herbarium in Canberra (CANB). He was an enthusiastic collector of bryophytes and lichens and developed the minuscule cryptogamic herbarium into the largest in the Southern Hemisphere. He also published numerous papers, mostly on the mosses and to a lesser extent on the lichens of Australia, New Guinea and the neighbouring islands (Fulwood 2001; Elix 2001). He had a plan, in cooperation with Vanuatu authorities, to investigate the imperfectly known bryoflora of these Pacific islands. He made a very effective two-week collecting trip to Vanuatu in October 1998 and returned with large number of bryophyte specimens (his collecting areas are marked on the map of fig. 1). He prepared a draft checklist of Vanuatu bryophytes (Streimann 1999) and asked me to update the Hepaticae part of the manuscript. Later he sent me large number of Vanuatu liverworts for identification. He published his first Vanuatu moss records (Streimann and Reese 2001), but his untimely death prevented him from continuing this project. Even his bulky new Catalogue of Australian Mosses, enumerating more than one thousand species, was published only after his death, in collaboration with Niels Klazenga (Streimann and Klazenga 2002).

In the meantime, the Department of Botany in the National Science Museum, Amakubo, Tsukuba, Japan, also initiated a project to explore the bryophyte flora of Vanuatu. They organized several collecting trips there and, as a result, produced a Checklist of the Mosses of Vanuatu (Higuchi 1996). This was followed by a 12-part series on the bryoflora of Vanuatu, beginning with an introduction (Higuchi 2002) with other parts mostly dealing with mosses, but also liverworts (Furuki 2002, Yamada and Hayashi 2003, Higuchi 2005) and hornworts (Hasegawa 2002).

In our herbarium (EGR), Andrea Sass-Gyarmati (2002) published the members of Ptychanthoideae subfamily of Lejeuneaceae from Streimann's collection, including a species new to science, *Caudalejeunea streimannii* Gyarmati. We intend to continue the identification of Streimann's legacy and begin with this further publication to deal with certain families from the rest of his liverwort collections. In this work, 59 specimens comprising 30 species, of which one genus and a total of 16 species proved to be new records for Vanuatu, 6 of which are new also to the Pacific realm.

List of the records

The asterisk before the species name indicates records new to Vanuatu. Two asterisks means that the genus is new for the islands, and three that they are new for the whole Pacific. The name of each species is followed by the list of localities, including elevation, latitude, longitude, a short indication of the habitat and the substrate, Streimann's collecting number and herbarium acronyms, where samples are deposited. Streimann was always accompanied by Mr. P. Ala as a local guide and co-collector. Finally, the Vanuatu and worldwide distributions are indicated.

Abbreviations used for the islands: **EF:** Efate, **ESP:** Espiritu Santo.

Abbreviations of common localities: *BBL:* Big Bay – Luganville Road, 26 km NW of Luganville, 15°19'S, 167°01'E, 380–410 m. Forest and regrowth on limestone ridge. *FDB:* Forestry Demonstration area, Butmas, 25 km NW of Luganville. 15°22'S, 167°00'E, 620 m. Tropical forest on moderate slope with *Myristica fatua* dominant. *FLA:* Forari logging area, 17 km ENE of Port Vila, 17°38'S, 168°27'E, 300 m. Lowland rainforest on broad undulating ridge. *McD:* Track to Mt McDonald, 14 km N of Port Vila, 17°36'S, 168°19'E, 450–600 m. Lowland tropical forest on narrow limestone ridge. *TAN:* Track to Mt Tanakar Plateau, Butmas, 26 km NW of Luganville, 15°22'S, 169°59'E, 700–720 m. Tropical forest on gentile limestone slopes.

ANTHOCEROTOPHYTA

1. *Folioceros appendiculatus* (Steph.) Haseg. [Anthocerotaceae] (Figs 2, 3)

ESP: Big Bay Road (near Sale River), 47 km NW of Luganville, 15°13'S, 166°52'E, 50 m. Exposed, sandy road cutting with seepage, with many globular gemmae, *H. Streimann 62711*, CANB. The mammilliform protrusion of gemma cells seems to be unusual (Fig. 3). **Distribution:** Malesian-Pacific species. Hasegawa (2002) published it under the name of *Anthoceros appendiculatus* Steph. From the same island. According to an earlier publication of Piippo (1993) the species is identical with the more widespread *Folioceros glandulosus* (Lehm. & Lindenb.) Bharadw. Based on the synonymy of Meijer (1957) and studies of the types.

MARCHANTIOPHYTA

2. *Ceratolejeunea cornuta* (Lindenb.) Schiffn. [Lejeuneaceae]

ESP: *FDB*, on branches of *Hibiscus tiliaceus*. *H. Streimann 62369 p.p.*, CANB. **EF:** *McD* on trunk. *H. Streimann 63219 p.p.* CANB. **Distribution:** It is known from Vanuatu, Aoka Island, under the name of *Ceratolejeunea maritima* (Spruce) Steph. (Müller et al. 1983). According to my opinion *Ceratolejeunea cornuta* is a Pantropical species, hardly distinguishable from *Ceratolejeunea belangeriana* (Pócs 2011), which is known from Madagascar to the Pacific islands.

3. **Cheilolejeunea trapezia* (Nees) Kachroo & R.M.Schust. [Lejeuneaceae]

ESP: *BBL* On semi-exposed *Macaranga* stem. *H. Streimann 62272 p.p.*, CANB, EGR. **EF:** *McD, H. Streimann 63219 p.p.* CANB. **Distribution:** Palaeotropic species rare in Africa and widespread in Indomalaya and the Pacific (Pócs et al. 2019).

4. *Chiastocaulon dendroides* (Nees) Carl. [Plagiochilaceae]

EF: *McD*, on shaded tree trunk. *H. Streimann 63302*, CANB; **ESP:** *TAN*, On shaded vine. *H. Streimann 62620*, CANB, EGR; *FDB, H. Streimann 62456*, CANB. **Distribution:** In Vanuatu only known from Nanua Lava Island. Widespread from Southeast Asia to Fiji and Tahiti (Inoue 1984; Renner et al. 2016).

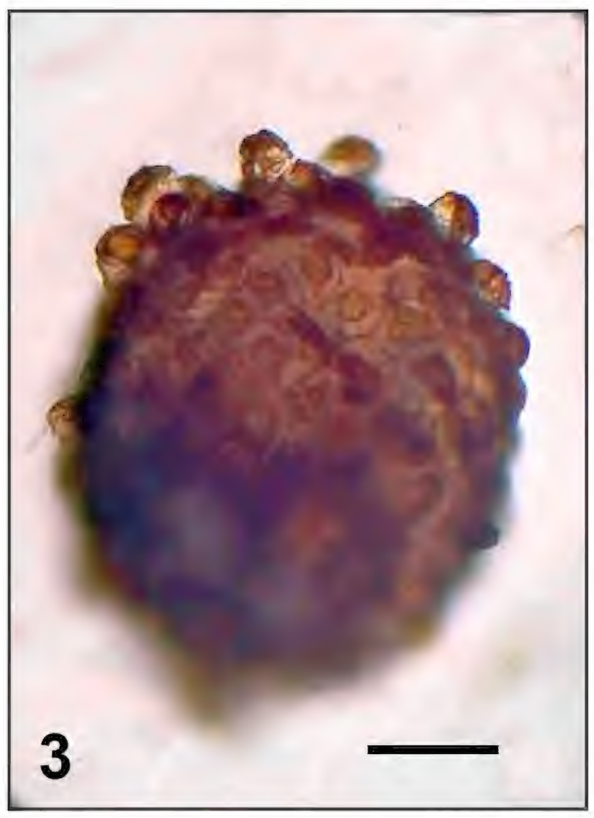
5.*Cololejeunea cocoscola Tixier [Lejeuneaceae] (Figs 4–6).

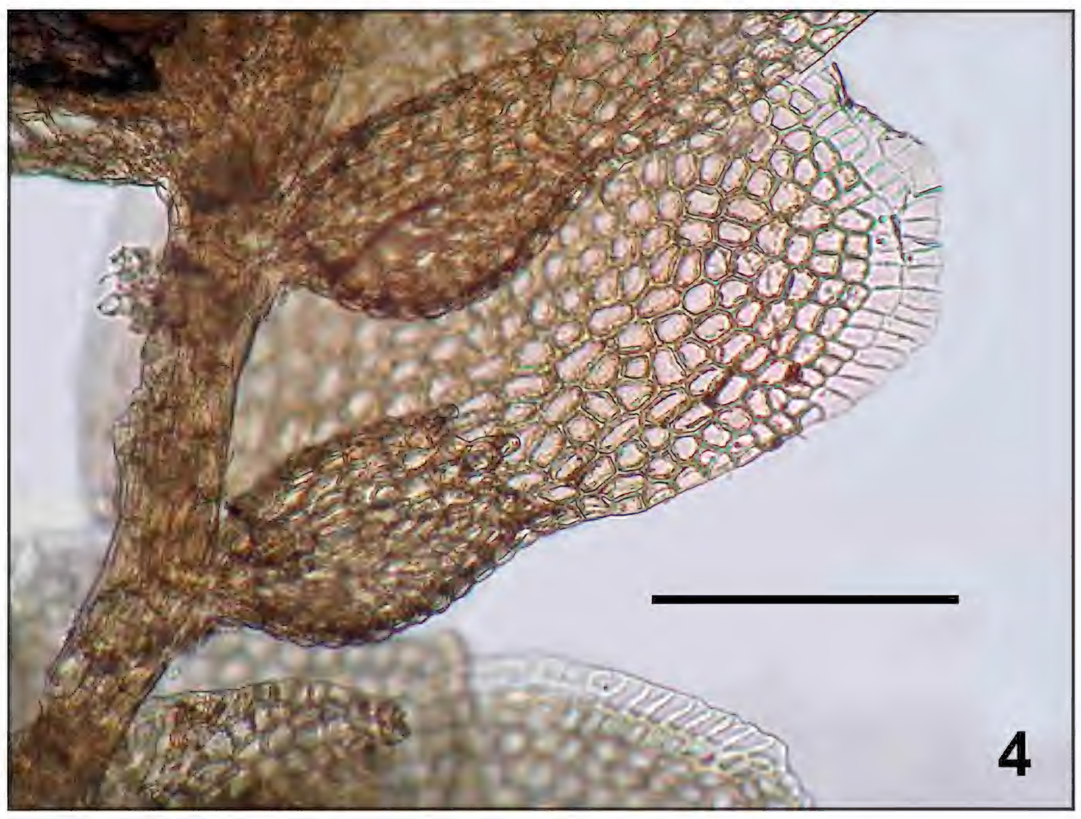
ESP: Luganville – Hog Harbour Road (over river) past Matevala Plantation, 16 km N of Luganville. 15°22'S, 167°11'E, 1 m. *Calophyllum inophyllum, Barringtonia asiatica* dominated strand vegetation. On shaded *Barringtonia* bark, *H. Streimann 62940 p.p.* **Distribution:** Hitherto known only from Tonga (Tixier 1993)

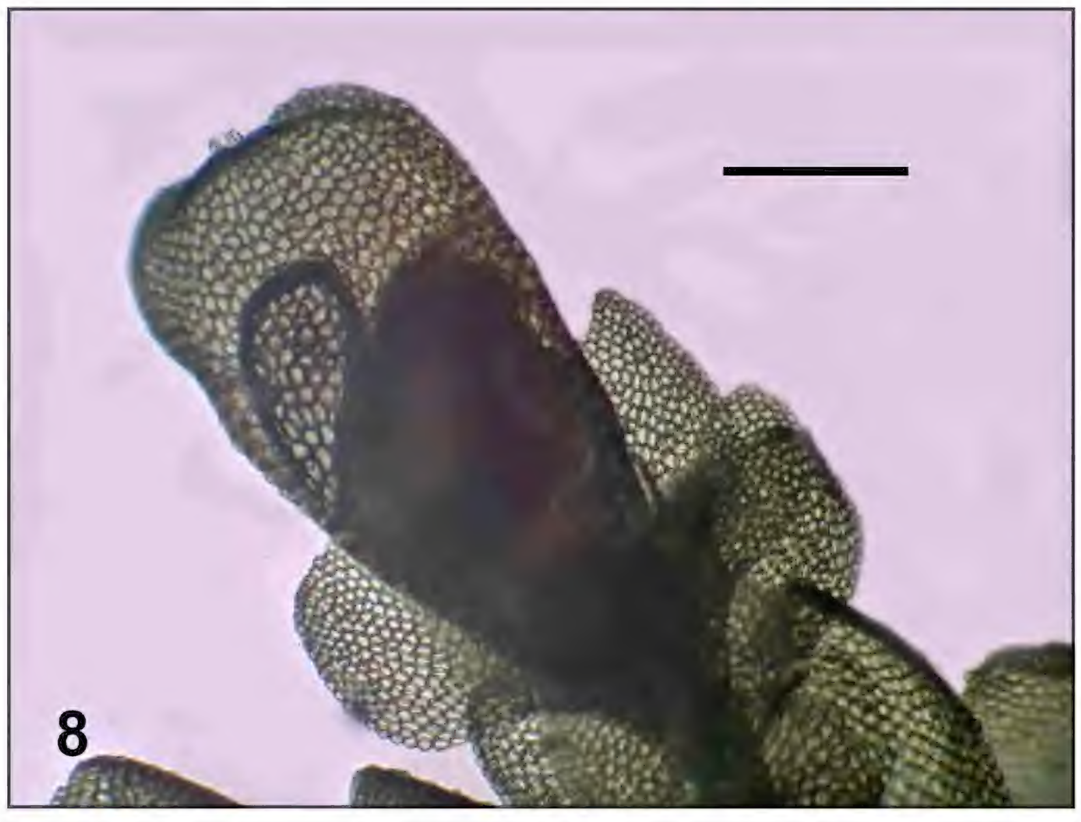
and from Fiji Islands (Pócs et al. 2011). Tixier described and depicted only sterile plants. Streimann's collection has perianths, which are cordate, flattened with a ventral fold and with very short, conical, one cell high beak. The bracts are almost as long as the perianth, lanceolate-ovate with rounded apex and hyaline margin. Usually, one subloral innovation is present.

6. *Cololejeunea hebridensis* Tixier [Lejeuneaceae]

EF: *McD*, epiphyllous on treelet leaves. *H. Streimann 63416*, CANB, PVV, TAL, EGR. **Distribution:** Hitherto known only from Vanuatu: Efate (Tixier 1975).







Figs 2–3: ***Folioceros appendiculatus*** (Steph.) Haseg.: 2. Habit, ventral view. Scale bar 500 µm. 3. Gemma. Scale bar 25 µm. **Figs. 4–6:** ***Cololejeunea cocoscola*** Tixier: 4. Habit, ventral view. Scale bar 200 µm. 5. Lobulus, ventral view. Scale bar 50 µm. 6. Perianth with bracts. Scale bar 100 µm. **Figs 7–8:** ***Lejeunea umbilicata*** (Nees) Nees in Gottsche: 7. Habit, ventral view. 8. Perianth. Scale bar 250 µm.

7. *Dumortiera hirsuta* (Swartz) Nees [Dumortieraceae]

ESP: *TAN*, tropical forest surrounding a narrow seasonal stream with limestone banks. On shaded calcareous bank, *H. Streimann 62682*, CANB, EGR. **Distribution:** Widespread in Vanuatu Islands (Furuki 2002). Oceanic Sub-cosmopolitan.

8. *Frullania nodulosa* (Reinw. et al.) Nees [Frullaniaceae]

EF: *FLA,* On fallen branch, *H. Streimann 63010*, CANB, EGR. **Distribution:** In Vanuatu known only from Espiritu Santo. Pantropical lowland rainforest species (Pócs 2008).

9. *Lejeunea adpressa Nees [Lejeuneaceae]

ESP: Luganville – Hog Harbour Road (over river) past Matevala Plantation, 16 km N of Luganville. 15°22'S, 167°11'E, 1 m. *Calophyllum inophyllum, Barringtonia asiatica* dominated strand vegetation. On shaded *Barringtonia* bark, *H. Streimann 62940 p.p.*, CANB, EGR; *FDB,* on shaded trunk. *H. Streimann 62406 p.p.*, CANB, EGR. **Distribution:** Widespread Pantropical species (Gradstein 2021).

10. *Lejeunea umbilicata (Nees) Nees in Gottsche [Lejeuneaceae] (Figs 7, 8).

ESP: *FDB*, on shaded trunk. *H. Streimann 62406 p.p.*, CANB, EGR. **Distribution:**. Malesian-Pacific species distributed from Sumatra to the Philippines and Samoa. (Pócs and Wei 2017).

11. *Mastigophora diclados* (Brid. ex Weber) Nees. [Mastigophoraceae]

EF: Ewor River, 26 km NE of Port Vila, 17°43'S, 168°33'E, 10 m. On streambed rocks (limestone), *H. Streimann* 63156, CANB. *McD*, *H. Streimann 63310, 63311,63313, 63316 p.p.*, CANB. **Distribution:** Widespread Palaeotropical species.

12. *Metzgeria leptoneura* Spruce [Metzgeriaceae]

ESP: *FDB,* on shaded trunk. *H. Streimann 62406 p.p.*, CANB, EGR. **Distribution:** Worldwide, suboceanic (So 2002).

13. * *Microlejeunea lunulatilobula* Horik [Lejeuneaceae]

ESP: *FDB,* on shaded trunk. *H. Streimann 62406 p.p.*, CANB. EF: *McD,* on trunk. *H. Streimann 63219 p.p.*, CANB. **Distribution:** Indomalayan-Pacific species (Miller et al. 1983).

14. ***Neolepidozia disparata (J.J.Engel & G.L.Merr.) E.D.Cooper [Lepidoziaceae] (Fig. 19).

EF: *McD*, On shaded rotting log. *H. Streimann 63410 p.p. min.*, CANB, EGR. **Distribution:** Hitherto known only from Australia, Queensland (Engel & Merrill 2004). New to the Pacific realm.

15. * *Plagiochila junghuhniana*** Sande Lac. [Plagiochilaceae] (Figs 9, 10).

EF: *FLA,* On semi-shaded vine. *H. Streimann 63029,* CANB; *McD*, On stem of thin shrub. *H. Streimann 63371*, CANB, EGR, PVV, NY. **Distribution:** Malayan-Pacific species (Inoue 1984).

16. * *Plagiochila perserrata*** Herzog [Plagiochilaceae] (Syn.: *Plagiochila hottae* Inoue) (See figs.11–12)

ESP: *FDB*, on medium sized *Hibiscus tiliaceus* branches. *H. Streimann 62371*, CANB, EGR; *BBL,* On shaded vine. *H. Streimann 62286 p.p.* CANB. **EF:** *McD*, on shaded treelet. *H. Streimann 6342*, CANB. **Distribution:** Scattered from Himalaya to Sabah (Inoue 1984, So 2001), new to the Pacific.

17. * *Plagiochila propinqua*** Sande Lac. [Plagiochilaceae]

EF: *McD*, on shaded tree roots and trunks. *H. Streimann 63306, 63369, 63377, 63395*, CANB, PVV, EGR, NY, TAL. **Distribution:** Malesian (Inoue 1984), new to the Pacific.

18. * *Plagiochila sciophila*** Nees [Plagiochilaceae] (Figs 13, 14).

ESP: *FDB*, on bark and rotten logs. *H. Streimann 62346, 62447,62482, 62489*, CANB, PVV, EGR; Mt Malel, 30 km NNW of Luganville, 15°15'S, 167°05'30"E, 180 m, disturbed forest on moderate slope with small limestone outcrops, on dead treelet stem, *H. Streimann 62241*, CANB; *BBL*, on semi-shaded prop roots of *Myristica fatua*, *H. Streimann 62261*, CANB, PVV, EGR; *TAN*, on shaded vine. *H. Streimann 62583, 62619, 62650*. CANB. **Distribution:** One of the most widespread Indomalayan-Pacific *Plagiochila* species (So 2001).

19. ***Plagiochila teysmannii Sande Lac. [Plagiochilaceae] (Figs 15, 16)

ESP: Nambauck Village (end of road), 12 km NW of Luganville. 15°27'S, 167°04'E, 170 m, disturbed forest on limestone, surrounding seasonal stream, on treelet branch, *H. Streimann 62094*, CANB. **Distribution:** Widespread in the Malayan archipelago (Inoue 1984) also in tropical Australia (So 2000): new to the Pacific realm.

20. *Plagiochila tjibodensis* Schiffn. [Plagiochilaceae]

ESP: *FDB*, on shaded trunk. *H. Streimann 62457*. CANB, PVV, EGR. **Distribution:** A rare Malayan species new to the Pacific. Rare Malesian species (Java, Inoue 1984); new to the Pacific realm.

21. ***Plagiochila vitiensis Mitt. [Plagiochilaceae] (Figs 17, 18).

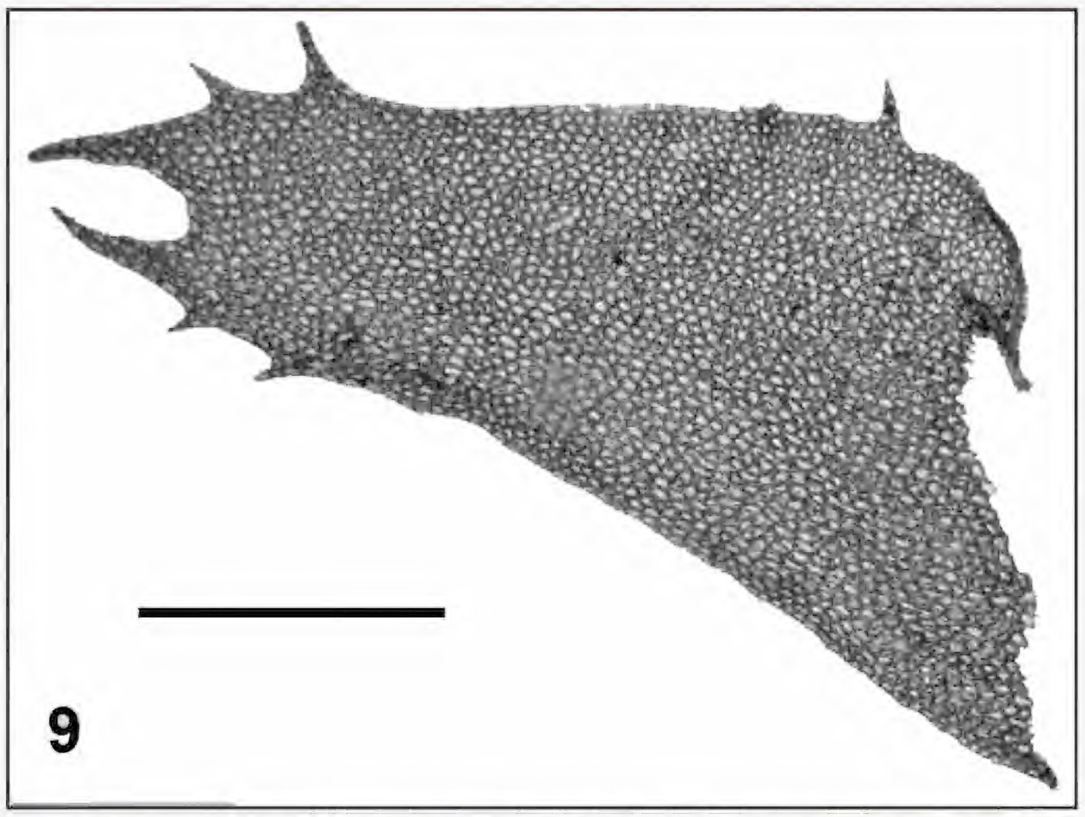
ESP: Track to Mt Tanakar, Butmas, 26 km NW of Luganville. 15°22'S, 169°59'E, 680 m, *Myristica fatua* and *Dysoxylum* dominated tropical forest on limestone, on shaded vine, *H. Streimann 62540*, CANB. **Distribution:** Widespread in Australasia and the Pacific Islands (Inoue 1981); no record from Vanuatu has been published.

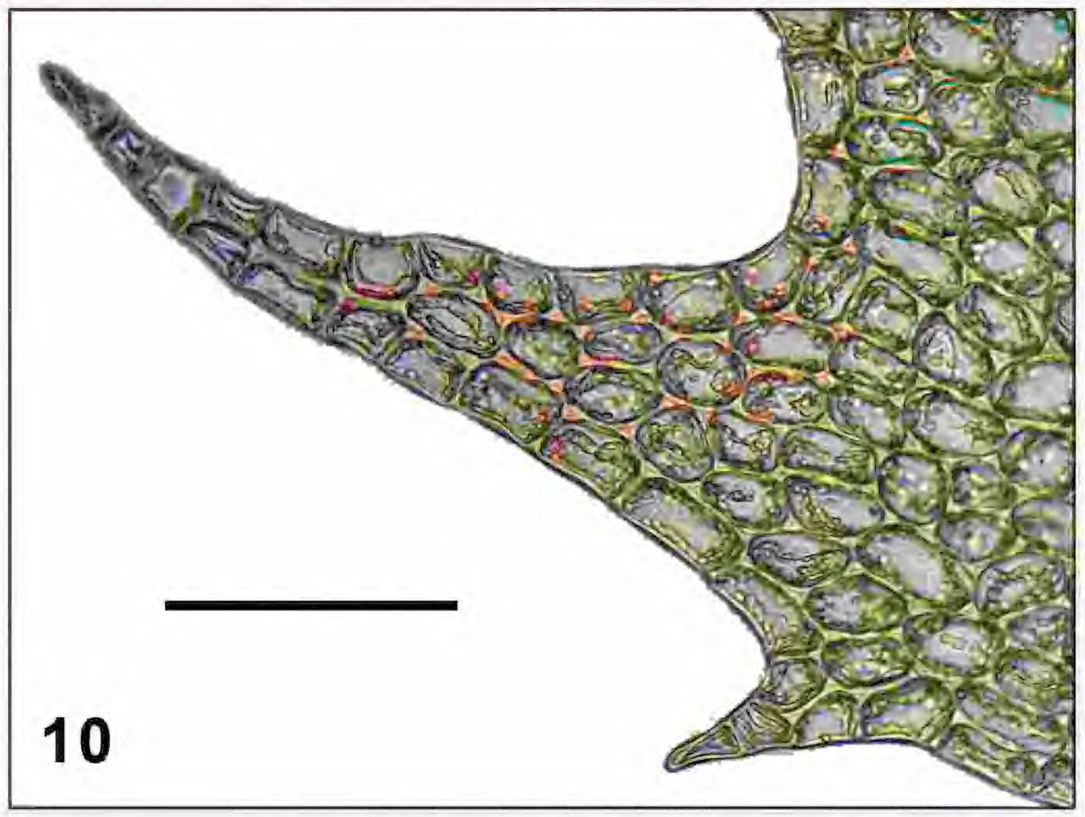
22. *Plicanthus hirtellus* (Brid. ex Weber) Nees [Anastrophyllaceae]

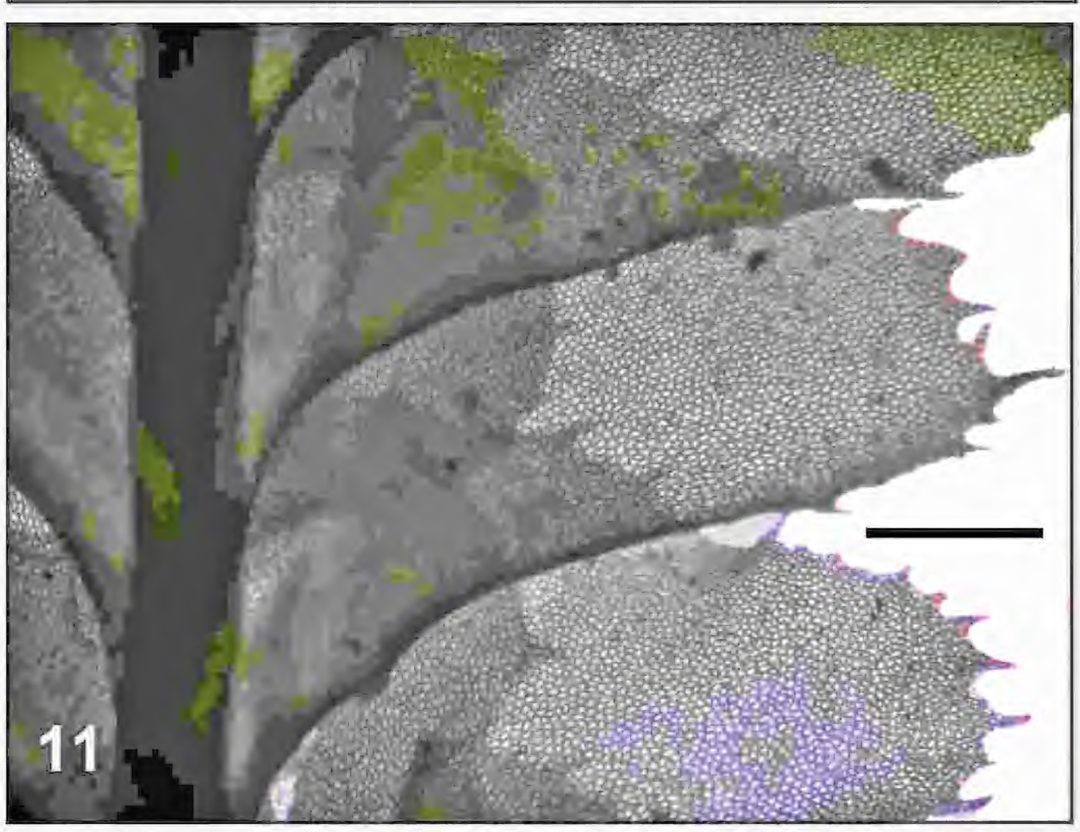
EF: *McD*, on trunks, *H. Streimann 63300, 63316 p.p., 63317*, CANB. **EF:** Ewor River, 26 km NE of Port Vila, on exposed rock in stream, *H. Streimann 63155*, CANB. **Distribution:** Widespread in Vanuatu and from Southeast Asia to the Pacific. It rarely occurs also in North America: British Columbia (Miller et al. 1983).

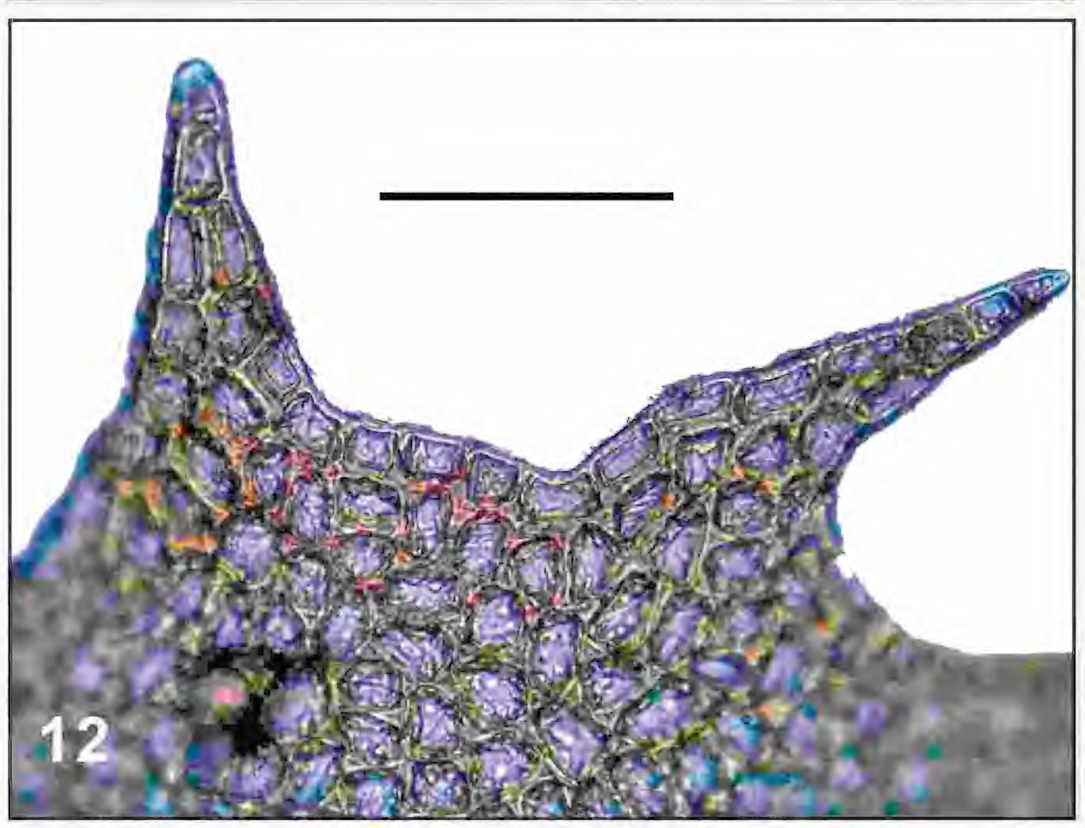
23. *Ptychanthus striatus* (Lehm. & Linenb.) Nees [Lejeuneaceae]

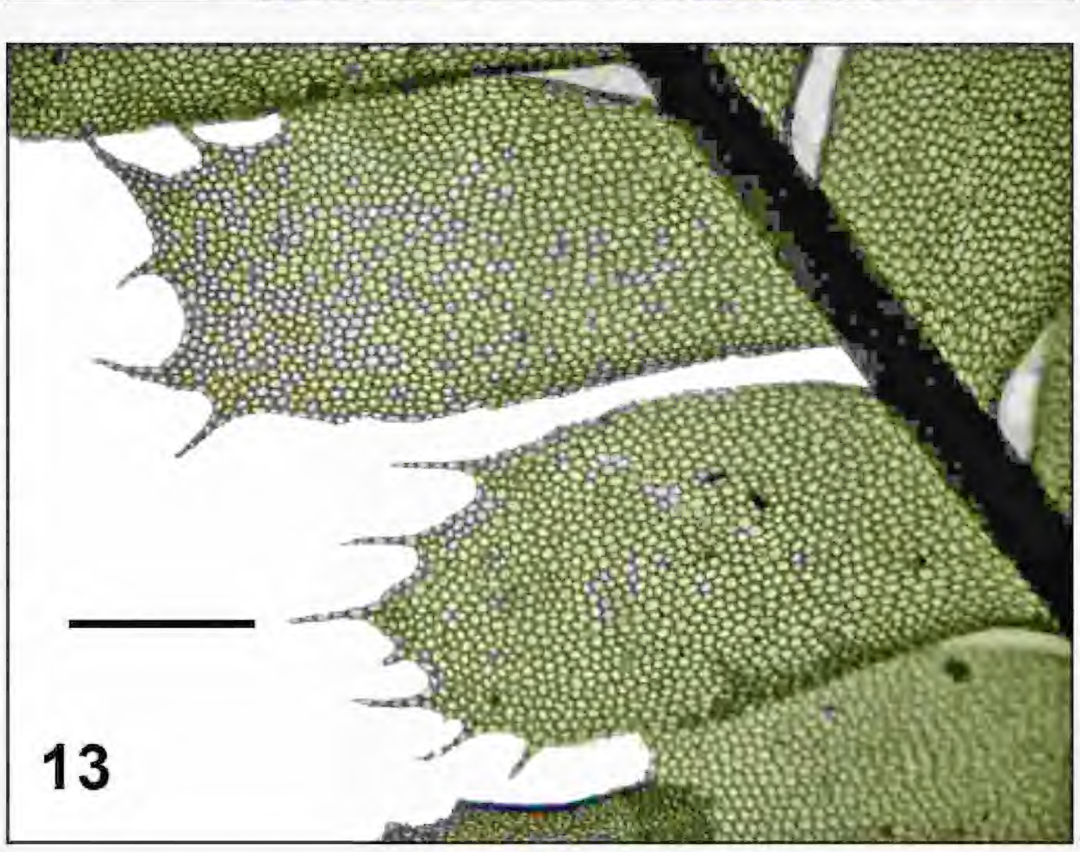
ESP: *BBL*, on shaded vine, *H. Streimann 62286 p.p.*, CANB; *FDB*, on live and dead trunks. *H. Streimann 62451, 62453*, CANB, PVV, EGR, NICH, TAL, NY, LE; *TAN*, on shaded treelet, *H. Streimann 62554*, CANB, EGR. **Distribution:** Widespread in Vanuatu and in the whole tropical Asia to the Pacific (Ahonen et al. 2005).

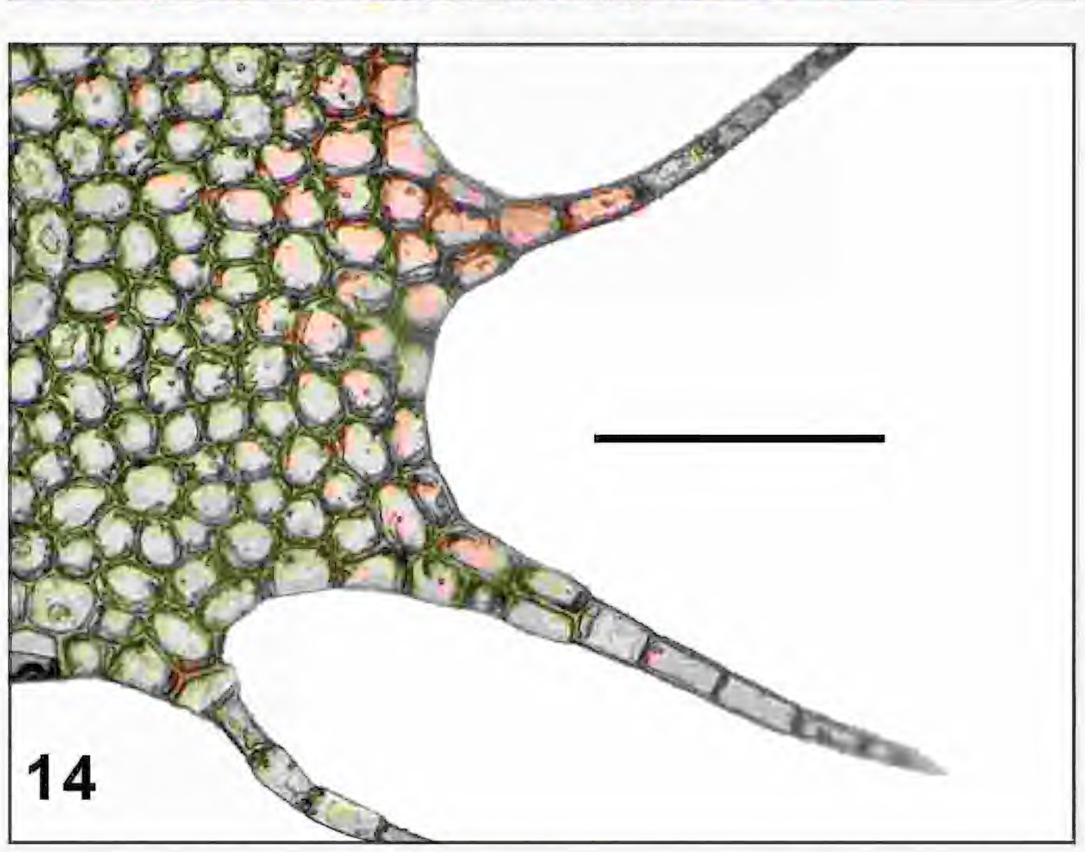












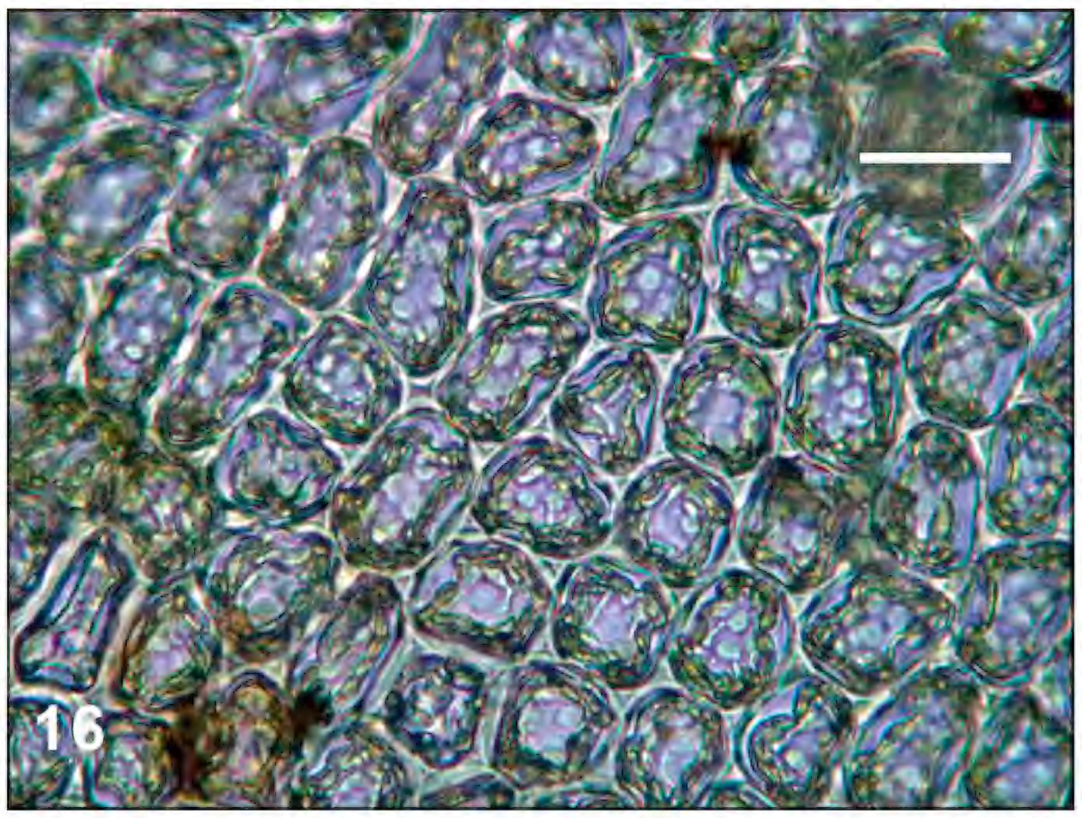
Figs. 9–10: ***Plagiochila junghuhniana*** Sande Lac.: 9. Leaf. Scale bar 500 µm. 10: Leaf apex. Scale bar 100 µm. **Figs. 11–12:** ***Plagiochila perserrata*** Herzog: 11. Habit, dorsal view. Scale bar 500 µm. 12. Leaf apex. Scale bar 50 µm. **Figs. 13–14:** ***Plagiochila sciophila*** Nees: 13. Habit, dorsal view. Scale bar 500 µm. 14: Leaf apex. Scale bar 100 µm.

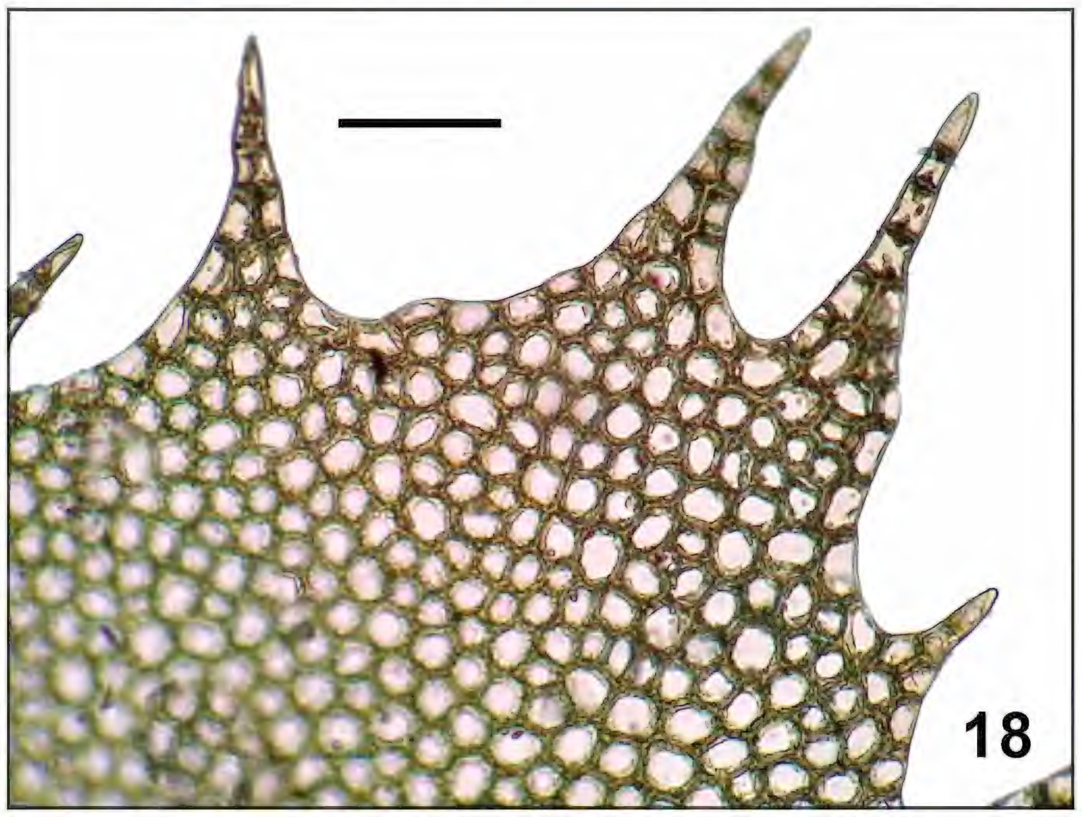
24. ***Radula javanica*** Gottsche [Radulaceae]

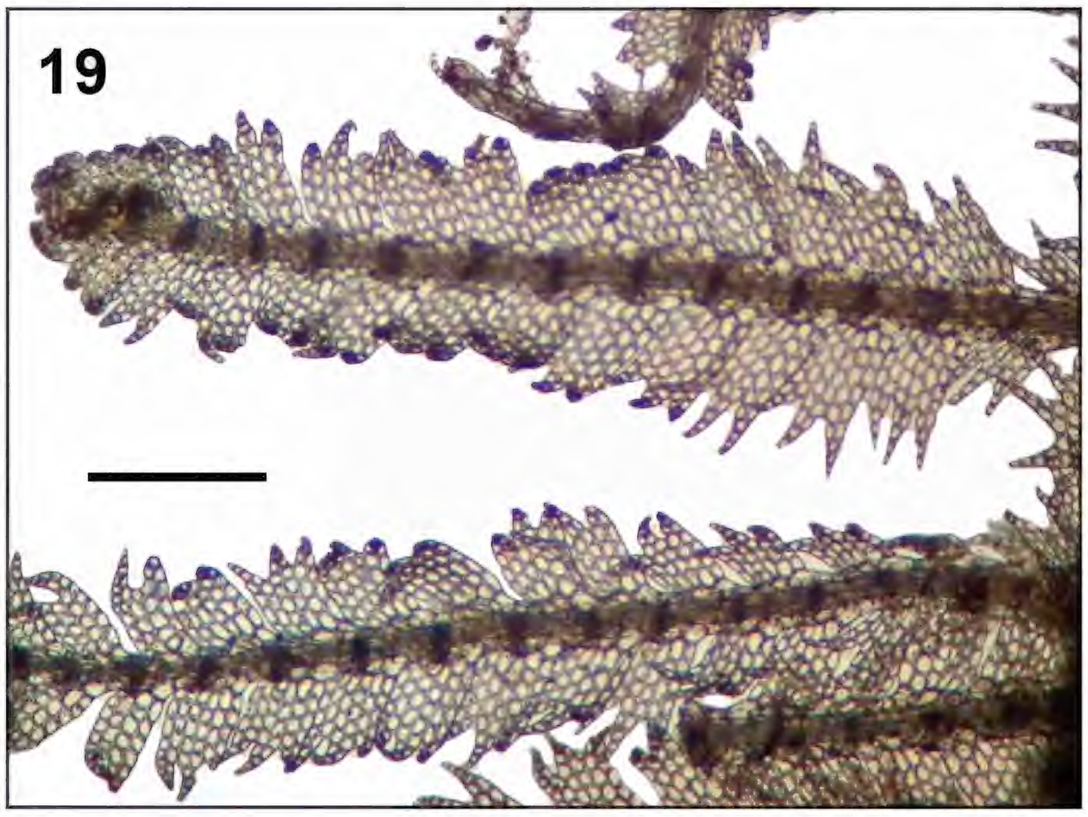
EF: *McD*, on canopy branches. *H. Streimann 63358*, CANB, PVV, EGR, NY, TAL. **Distribution:** Known from Vanuatu: Futuna and Sanma. Widespread Indomalesian-Pacific species (Miller et al. 1983).

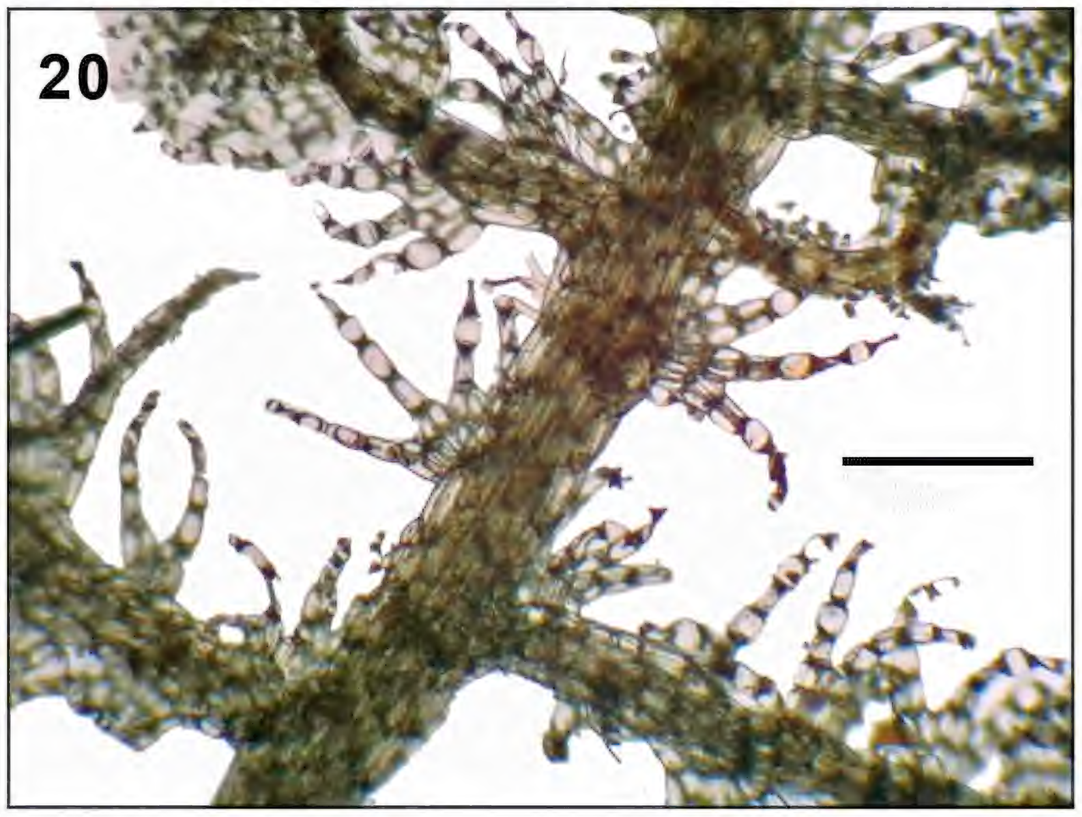
25. ***Radula reflexa*** Nees & Mont. [Radulaceae]

ESP: *FDB*, on treelet stem, *H. Streimann 62337*, CANB, PVV, EGR; Sevua Village near Nambauck Village, 15 km NW of Luganville. 15°27'S, 167°04'E, 170 m, *H. Streimann 62141*, CANB, EGR. **Distribution:** Known from Vanuatu: Espiritu Santo, then from Amboina, Ceram, Borneo, New Guinea to Samoa (Miller et al. 1983).









Figs. 15–16: ***Plagiochila teysmannii*** Sande Lac.: 15. Habit, dorsal view. Scale bar 500 µm. 16: Median lobe cells. Scale bar 25 µm. **17–18:** ***Plagiochila vitiensis*** Mitt.: 17: Habit, dorsal view. Scale bar 500 µm. 18. Leaf apex. Scale bar 100 µm. **19:** ***Neolepidozia disparata*** (J.J.Engel & G.L.Merr.) E.D.Cooper: Side branches, ventral view. Scale bar 250 µm. **20:** ***Tricholepidozia quadriseta*** (Steph.) E.D.Cooper: Part of shoot with side branches, dorsal view. Scale bar 250 µm.

26. ***Radula retroflexa*** Taylor [Radulaceae]

EF: *FLA*, on shaded buttress, *H. Streimann 62993*, CANB, PVV, EGR, NY. **Distribution:** Widespread Indomalesian-Pacific species known also from Vanuatu (Yamada 1979).

27. ***Schistochila aligera*** (Nees & Blume) J.B.Jack & Steph. [Schistochilaceae]

EF: *McD*, on trunk, *H. Streimann 63261, 63303, 63304, 63382*, CANB, PVV, EGR, NY. **Distribution:** Widespread Indomalayan-Pacific species, known from Vanuatu: Vanua Lava (Miller et al. 1983).

28. **_Schiffneriolejeunea pulopenangensis_ (Gottsche) Gradst. [Lejeuneaceae]

ESP: _BBL_ on semi-exposed *Macaranga* stem, *H. Streimann 62272 p.p.*, CANB, EGR. **Distribution:** Widely distributed in Indomalesia from Sri Lanka to New Caledonia (Gradstein 2015). There are map records also from Norfolk Island and Fiji (AVH 2024); the genus is new to Vanuatu.

29. *_Spruceanthus planiusculus_ (Mitt.) X.Q.Shi, R.L.Zhu & Gradst. [Lejeuneaceae]

ESP: Logging area near Lavatmas (N of Sara), 48 km NNW of Luganville, 15°07'S, 167°01'E, 300 m, poor lowland forest on flats dominated by *Endospermum medullosum, Antiaris toxicaria* and *Pometia pinnata*, on canopy branches of *Macaranga*, *H. Streimann 62827*, CANB, EGR. **Distribution:** Widespread Indomalayan-Pacific species (Wang et al. 2016), but new to Vanuatu.

30. ***_Tricholepidozia quadriseta_ (Steph.) E.D.Cooper [Lepidoziaceae]. (Fig. 20).

ESP: _TAN_, on shaded humus rich ground on track, *H. Streimann 62591*, CANB, EGR.

EF: _McD_, on shaded rotting log, *H. Streimann 63409, x63410 p.p. max.*, CANB, EGR. **Distribution:** Hitherto known only from Queensland and New South Wales in Australia, Queensland (Engel and Merrill 2004). New to the Pacific realm.

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References

Ahonen I, Sass-Gyarmati A, Pócs T (2005) Molecular, morphological and taxonomic evaluation of the *Ptychanthus striatus* (Lejeuneaceae, Marchantiophyta) complex. *Acta Botanica Hungarica* 47: 226–246. DOI

AVH (2024) Australian Virtual Herbarium. Atlas of Living Australia. URL

Chew W-L (1975) The phanerogamic flora of the New Hebrides and its relationships. *Philosophical Transactions of the Royal Society B* 272: 315–328. DOI

Elix J (2001) Obituary - Vale Heinar Streimann, 1938–2001. *Folia Cryptogamica Estonica* 38: 87–88.

Engel JJ, Merrill GLS (2004) Austral Hepaticae. 35. A taxonomic and phylogenetic study of *Telaranea* (Lepidoziaceae), with a monograph of the genus in temperate Australasia and commentary on extra-Australasian taxa. *Fieldiana Botany*, n.s. 44: 1–265. DOI

Fulwood M (2002) Eulogy. Pp.1–4 in Ramsay H (ed.), Streimann, Heinar (1938 – 2001) *Australian Bryological Newsletter* 45: 1–6.

Furuki T (2002) Studies on the bryophyte flora of Vanuatu. 5. Metzgeriales and Marchantiales (Hepaticae). *Annals of the Tsukuba Botanical Garden* 21: 95–101.

Gradstein SR (2015) An overview of the genus *Schiffneriolejeunea* (Marchantiophyta: Lejeuneaceae). *Nova Hedwigia* 100: 507–524. DOI

Gradstein SR (2021) The liverworts and hornworts of Colombia and Ecuador. *Memoirs of the New York Botanical Garden* 121: 1–723. DOI

Hasegawa J (1986) The Anthocerotae collected by Drs. Z. Iwatsuki and N. Kitagawa in New Caledonia and Fiji. *The Journal of the Hattori Botanical Laboratory* 60: 379–390.

Hasegawa J (2002) Studies on the bryophyte flora of Vanuatu. 6. Anthocerotae. *Annals of the Tsukuba Botanical Garden* 21: 103–107.

Higuchi M (1996) A checklist of the mosses of Vanuatu. *Bulletin of the National Science Museum, Tokyo,* Ser. B 22: 113–134.

Higuchi M (2002) Studies on the bryophyte flora of Vanuatu. 1. Introduction and Mniaceae (Musci). *Annals of the Tsukuba Botanical Garden* 21: 73–77.

Higuchi M (2005) Studies on the bryophyte flora of Vanuatu. 8. Field studies in 2000 and 2001 and Haplomitriaceae and Treubiaceae (Hepaticae). *Bulletin of the National Science Museum, Tokyo,* Ser. B 31: 11–17.

Inoue H (1981) Notes on the Plagiochilaceae, XI. A review of the species of *Plagiochila* (Dum.) Dum. from Samoa. *The Journal of the Hattori Botanical Laboratory* 49: 335–357.

Inoue H (1984) *The genus* Plagiochila *(Dum.) Dum. in southeast Asia*. (Academia Scientific Book, Tokyo)

Meijer W (1957) Notes on some Malaysian species of *Anthoceros* L. (Hepaticae). II. *The Journal of the Hattori Botanical Laboratory* 18: 1–13.

Miller HA, Whittier HO, Whittier BA (1983) Prodromus florae hepaticarum Polynesiae. Catalogue of Hepaticae and Anthocerotae. *Bryophytorum Bibliotheca* 25: 1–423.

Mitten W (1868) A list of the Musci collected by the Rev. Thomas Powell in the Samoa or Navigator's Islands. *The Journal of the Linnean Society, Botany* 10: 166–195. DOI

Mueller-Dombois D, Fosberg FR (1998) *Vegetation of the tropical Pacific islands*.(Springer: New York) DOI

Munzinger J (2009) Vanuatu. In Gillespie RG, Clague DA (eds), *Encyclopedia of Islands*. pp. 939–941. (University of California Press: Berkeley)

Piippo S (1993) Bryophyte flora of the Huon Peninsula, Papua New Guinea. LIV. Anthocerotophyta. *Acta Botanica Fennica* 148: 27–51.

Pócs T (2008) Bryophytes from the Fiji Islands, IV. The genus *Frullania* Raddi (Jungermanniopsida), I., with description of *F. vivipara* Pócs, spec. nov. *Fieldiana Botany*, n.s. 47: 147–158. DOI

Pócs T (2011) East African Bryophytes XXIX. The *Ceratolejeunea* (Lejeuneaceae) species in the Indian Ocean islands. *Polish Botanical Journal* 56: 131–153.

Pócs T, Mizutani M, Koponen T (2019) Bryophyte flora of the Huon Peninsula, Papua New Guinea. LXXX. *Cheilolejeunea* and *Drepanolejeunea*, with contributions to *Ceratolejeunea, Cololejeunea*, *Diplasiolejeunea*, *Lejeunea*, *Leptolejeunea*, *Metalejeunea* and *Microlejeunea* (Lejeuneaceae, Marchantiophyta). *Acta Bryolichenologica Asiatica* 8: 41–84.

Pócs T, Sass-Gyarmati A, Naikatini A, Tuiwawa M, Braggins J, Pócs S, von Konrat M (2011) New liverwort (Marchantiophyta) records for the Fiji Islands. *Telopea* 13: 455–494. DOI

Pócs T, Wei Y-M (2017) Bryophytes from the Fiji Islands, VIII. The genus *Lejeunea* Libert (1820) (Jungermanniopsida). In Telnov D, Barclay MVL, Pauwels OSG (eds), *Biodiversity, biogeography and nature conservation in Wallacea and New Guinea*. Volume III. pp. 9–20. (The Entomological Society of Latvia: Riga). URL

Renner MAM, Heslewood MM, Patzak SD, Schäfer-Verwimp A, Heinrichs J (2016) The genera *Chiastocaulon, Cryptoplagiochila* and *Pedinophyllum* (Plagiochilaceae) in Australia. *Australian Systematic Botany* 29 (4/5): 358–402. DOI

Sass-Gyarmati A (2002) *Ptychanthoideae* (subfam. of Lejeuneaceae, Hepaticae) from Vanuatu, with the description of *Caudalejeunea streimannii* Gyarmati sp.n. *Tropical Bryology* 22: 125–134. DOI

So ML (2000) *Plagiochila* sect. *Contiguae* (Hepaticae) in Australasia and the Pacific, with description of *Plagiochila subjavanica* sp. nov. *Australian Systematic Botany* 13: 803–815. DOI

So ML (2001) *Plagiochila* (Hepaticae, Plagiochilaceae) in China. *Systematic Botany Monographs* 60: 1–214. DOI

So ML (2002) *Metzgeria* (Hepaticae) in Australasia and the Pacific. *New Zealand journal of Botany* 40: 603–627. DOI

Stephani F (1914) Hepaticae Australes. *Journal and Proceedings of the Royal Society of New South Wales* 48: 94–135. DOI

Stephani F (1906–1917) *Species Hepaticarum* 3–5. (Georg and Cie: Geneva and Bâle)

Streimann H (1999) *Catalogue of the mosses of Vanuatu*. 74 pp. (Unpublished manuscript)

Streimann H, Klazenga N (2002) *Catalogue of Australian mosses*. Flora of Australia Supplementary Series 17. (Australian Biological Resources Study, Canberra).

Streimann H, Reese WD (2001) Vanuatu moss records. *The Journal of the Hattori Botanical Laboratory* 91: 295–300.

Tixier P (1973) Bryophytes exotiques. *Bulletin du Muséum National d'Histoire Naturelle. Botanique*.10: 73–86.

Tixier P (1974) Bryophytes exotiques: Bryophytes des Nouvelles-Hébrides (expedition de la Royal Society). *Bulletin du Muséum National d'Histoire Naturelle. Botanique*.16: 33–45.

Tixier P (1975) Contribution à l'étude du genre Cololejeunea V. Quelques espèces de la region indo-pacifique. *Botaniska Notiser* 128: 425–431.

Vitt DH (1991) Distribution patterns, adaptive strategies, and morphological changes along elevational and latitudinal gradients of South Pacific islands. Pp. 205–231 in Nimis PL, Crovello TJ (eds) *Quantitative approaches to phytogeography*. (Kluwer Academic Publishers: Dordrecht) DOI

Wang J, Zhu R-L, Gradstein R (2016) Taxonomic revision of Lejeuneaceae subfamily Ptychanthoideae (Marchantiophyta) in China. *Bryophytorum Bibliotheca* 65: 1–141.

Yamada K (1979) A revision of Asian taxa of *Radula*, Hepaticae. *The Journal of the Hattori Botanical Laboratory* 79: 201–322.

Yamada K, Hayashi M (2003) Studies on the bryophyte flora of Vanuatu. 8. *Heteroscyphus* (Geocalycaceae, Hepaticae). *Bulletin of the National Science Museum, Tokyo*, Ser. B 29: 149–152.

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Riccardia dimorpha sp. nov. (Hepaticophyta, Aneuraceae) from Western Nelson, New Zealand, exhibiting sexually determined morphological dimorphism, an overlooked feature of some liverworts

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Abstract

Riccardia dimorpha is described from 24 collections made in New Zealand between 1984 and 2020 from Western Nelson, Westland, and Fiordland ecological provinces in the South Island, and from Stewart Island / Rakiura. These specimens were misidentified as *R. browniae* [*R. pusilla* (Steph.) E.A.Br., nom. illeg.], *R. asperulata* R.M.Schust., *R. multicorpora* E.A.Br., and *R. perspicua* E.A.Br., or identified only to genus. *Riccardia dimorpha* belongs to the *Riccardia* section *Alcicornia* Hässel and is characterised by having strong striations on the epidermis, a subterete thallus, a monopodial growth form, endomycorrhizae absent from the ventral epidermis, and epidermal cells are the same size as internal cells. Specimens were collected in fire-induced *Leptospermum scoparium* shrublands, on peat soils at lowland to montane elevations. *Riccardia dimorpha* is sexually dimorphic in plant size and number of branches (meristematic tip number), and male and female plants differ to the degree that the sexuality of a plant can be determined without finding sexual branches on a plant. Such dimorphism is rarely reported in liverworts although is common in mosses.

Keywords: *Aneuraceae*, *Riccardia*, New Zealand, new species, endemic, liverwort, sexual dimorphism

Introduction

The genus *Riccardia* was revised by Hewson (1970) for Australia and by Brown and Braggins (1989) for New Zealand. No new species for either country has been described since those treatments were published. The publication in Brown and Braggins (1989) of two new species known at the time only from the Glasgow Range, Western Nelson (*Riccardia pennata* E.A.Brown and *R. intercellula* E.A.Brown) signalled that further undiscovered species were likely in Western Nelson. Of 30 species recognised in New Zealand by Brown and Braggins (1989), 19 are endemic (63%). The non-endemic species are mostly shared with Australia (10 species). As currently circumscribed, *Riccardia crassa* is also widespread in Asia. *Riccardia alcicornis* is present in South America, Australia, and New Zealand, and *R. alba* is present in Fiji, Australia, and New Zealand.

While determining *Riccardia* specimens identified only to genus and checking determinations of other species for the liverwort flora project (Engel and Glenny 2008, 2019a,b) it was noticed that most specimens identified as *R. browniae* A.Hagborg & L.Söderstr. (Hagborg and Söderström, 2022) did not fit that species as described by Brown and Braggins (1989, as *R. pusilla* (Steph.) E.A.Br., nom. illeg.). These anomalous

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specimens did not fit any other New Zealand species treated by them, and are described below as *Riccardia dimorpha*. *Riccardia* collections at CHR were searched to find more overlooked material. Specimens of *R. alcicornis*, *R. asperulata*, *R. crassa*, *R. multicorpora*, *R. perspicua*, *R. browniae, Acromastigum anisostomum*, and *Telaranea inaequalis* R.M.Schust. from *Leptospermum* shrublands in the western South Island and Stewart Island / Rakiura were examined, and many more specimens were found in this way. Field trips were made in 2020 to two localities to collect fresh plants.

Sexually determined dimorphism, also termed dimorphism in secondary sexual characteristics (Lloyd and Webb 1977), is well studied in dioecious flowering plants (Delph 1999; Barrett and Hough 2013) but rarely commented on in the liverwort literature. It is well known in the mosses with the phenomenon of dwarf males: one third of dioicous pleurocarpous mosses may have dwarf males (Hedenas and Bisang 2011). However, in the liverworts it is only reported in a few species. *Sphaerocarpos* has male vegetative parts very reduced in size relative to the female. Schuster (1992: 811) describes *S. texanus* Aust. males as 10–20% the size of females. *Cryptothallus mirabilis* Malmb. also has dwarfed male plants (Schuster 1992: 574).

Furuki (1991) reported, "The dioicous species [of *Riccardia*] usually show sexual dimorphism: the male thalli are smaller and less branched than those of the female." Furuki (1991) in his morphological notes also mentioned sexual dimorphism as present in *R. pusilla* Grolle and *R. marginata* var. *pacifica* Furuki, with male plants of those two taxa less than 2 mm long. However, Furuki did not incorporate the dimorphism in size into his descriptions of the species. Brown and Braggins (1989) say of *Riccardia asperulata* R.M.Schust. "There may be a tendency for male thalli to be smaller than the female ones but very few mixed populations were examined". Sexually determined dimorphism is not commented on by Hewson (1970) or Hässel de Menendez (1972) however *R. longioleata* Hässel is illustrated as dimorphic with two female plants illustrated as being shorter and more richly branched than a single male plant (Hässel de Menendez 1972: 32, Fig. 6a–c). This dimorphism is of the same type as that observed in *R. dimorpha*. Because of conflicting accounts of sexual dimorphism in *Riccardia*, it is quantified here for *R. dimorpha*.

Methods

Dried plants were soaked briefly in warm water then soaked in pure domestic bleach for a few minutes until the thallus was clear, rinsed in water, stained with 0.2% methylene blue for a few seconds, then rinsed again in water (the 'bleach and blue' method of Rico 2011; cited in Reeb and Bardat 2014). This method aims to show surface features such as surface texturing, hyaline papillae, and rhizoids. Reeb and Bardat (2014) note that "bleach has the property of reinflating the old collapsed thalli, and the methylene blue rigidifies them, making possible nice cross sections". Light microscope photographs were taken with a Leica DMLB400, usually using differential interference contrast. SEM photography was done using a desktop Hitachi TM3050Plus microscope, after sputter-coating the dry specimen with gold.

Terminology follows Brown and Braggins (1989) for most parts, such as stolons and slime papillae. However, the parallel thickenings on the epidermal surface of species such as *R. crassa* and *R. perspicua* are usually referred to as striations (e.g. Hässel de Menendez 1972; Brown and Braggins 1989). Striations are literally scratches (i.e. indentations in the surface) rather than ridges, as occurs in *R. dimorpha*, *R. crassa*, and *R. perspicua*. Furuki (1991) uses the better term 'striately verrucose' for the ornamentation of *R. crassa*, and this terminology is used here.

Sexual dimorphism was quantified using characters that are visibly different in male and female plants: plant length from the base of the oldest living tissue of the main axis to the shoot apex furthest from the base, number of meristematic tips per plant, and main axis width measured between pinnae at about halfway between base an apex. In the 32 samples, 11 female plants and 21 male plants were measured. A balanced two-way ANOVA test was performed on measurements from 11 female and a randomly chosen subset of 11 male plants.

Results

Of 23 collections of *Riccardia dimorpha*, 15 were found to be female, six male, and two had male and female plants mixed.

Mean length of male plants was 10.5 mm (range 6–18 mm, n=21) and mean length of female plants was 7.7 mm (range 4.5–13 mm, n=11). Mean number of meristematic tips per plant in male plants was 11.2 (range 4–24, n=21) and mean number of tips per female plant was 25.5 (range 12–42, n=11). Main axis width did not differ. A two-way ANOVA rejected the null hypothesis that male and female plants do not differ in plant length and number of tips per plant do not differ ($p=0.000147$ and $p=0.000103$ respectively).

The dark brown cellular inclusions mentioned in the description are not normal oil-bodies as they are relatively unaffected by bleach and do not decay in dried specimens. However, they have a similar granular structure to oil-bodies (Fig. 5c). The inclusions are not stained by lactophenol cotton blue as would be expected for fungal pelotons. Also, they have an unusual intramarginal position that is not usually seen in endomycorrhizae or oil-bodies. They are not mentioned by Hässel de Menendez (1972) or Brown and Braggins (1989) and I have not seen them in other New Zealand *Riccardia* specimens. The inclusions were found in one male and one female collection of the 23 collections examined and were present in all plants in those two collections.

Taxonomy

Riccardia dimorpha Glenny, *sp. nov.*

Type: New Zealand: Western Nelson, Stockton Plateau, T35 Stream, 580 m, 171.906°E, 41.661°S, *Chionochloa juncea – Leptospermum scoparium / Empodisma minus – Gleichenia microphylla* low scrub in marsh with open soil areas and shallow temporary pools, with *Kurzia hippuroides*, *Pallavicinia rubristipa*, and *Riccardia crassa*, male plants, brown inclusions present, 28 Oct 2008, *D. Glenny 10326* (holotype: CHR 603443; isotype: F).

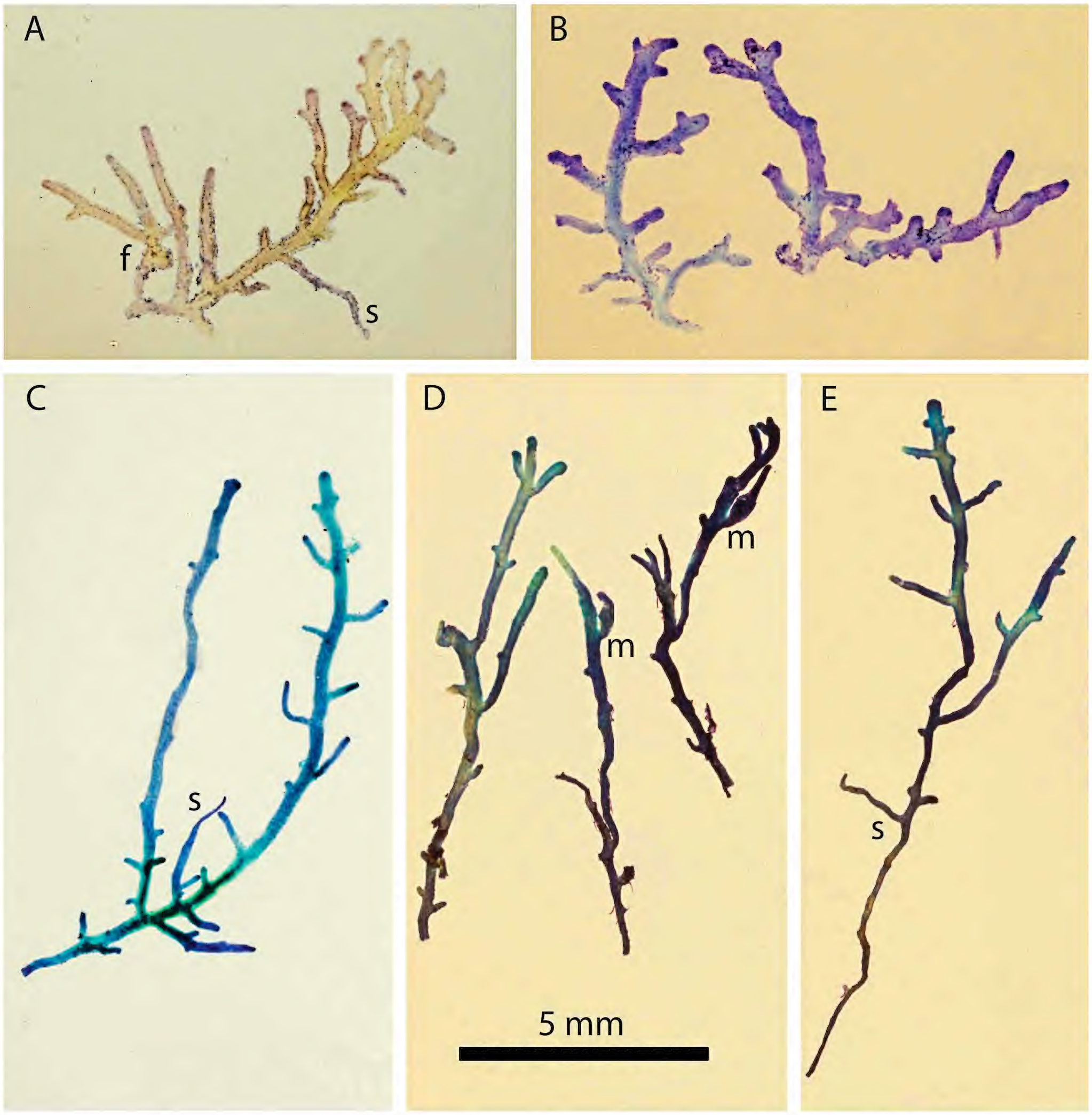

Fig. 1. *Riccardia dimorpha*, whole male and female plants. Female plants: A, B. Male plants: C, D, E. A photographed from CHR 668220, B from CHR 638186, C from CHR 603443, D and E from CHR 518930. 5 mm scale bar applies to all. f = female branch, m = male branch, s = stolon.

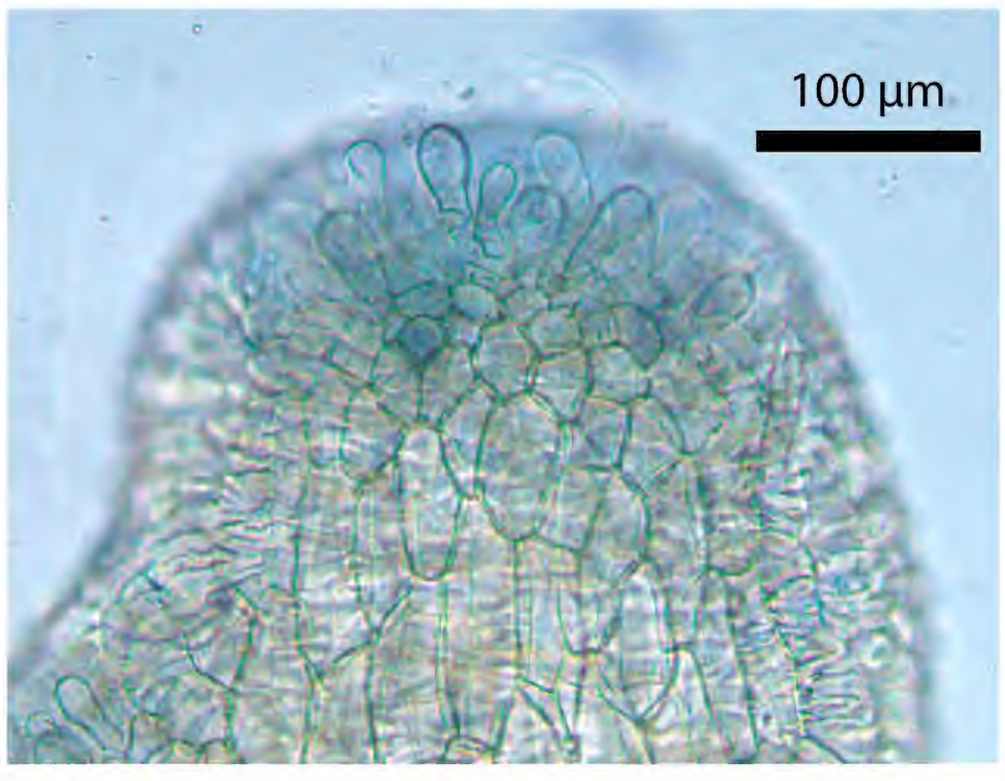

Fig. 2. *Riccardia dimorpha*, ventral view of shoot apex showing clavate slime papillae, the apical meristem cell on the ventral side of the branch. A mucus cap produced by the papillae is just visible. Photographed from CHR 638186.

Plants sexually dimorphic, male plants 6–18 mm long, female plants 4.5–13 mm long (Fig. 1). Meristematic tips per plant (i.e. branch tips) in male plants 4–24 per plant, in female plants 12–42 per plant, plants 1.5–4.5 mm wide including branches, loosely prostrate, green throughout, with a distinct main axis and side branches. Branching alternate to subopposite, with simple pinnae up to 2 mm long, pinnae sparsely branching or showing continued development to 9 mm long. Thallus and apex branches rounded at apex, without an apical sinus. Mucilage papillae in a transverse row at the apex or slightly ventral to the apex and projecting apically, usually not persisting on ventral surface but sometimes persisting to about halfway to the base of the plant and scattered over the whole ventral surface, never in 2 rows, absent from the dorsal surface; 33–45(60) µm long, 13–28 µm diameter at widest, clavate and narrowed to a 10 µm diameter base attachment, outer surface smooth, walls thin to 4 µm thick at apex (Fig. 2). Rhizoids not seen. Stolons occasional (1 or 2 per plant), sometimes developing from normal branches

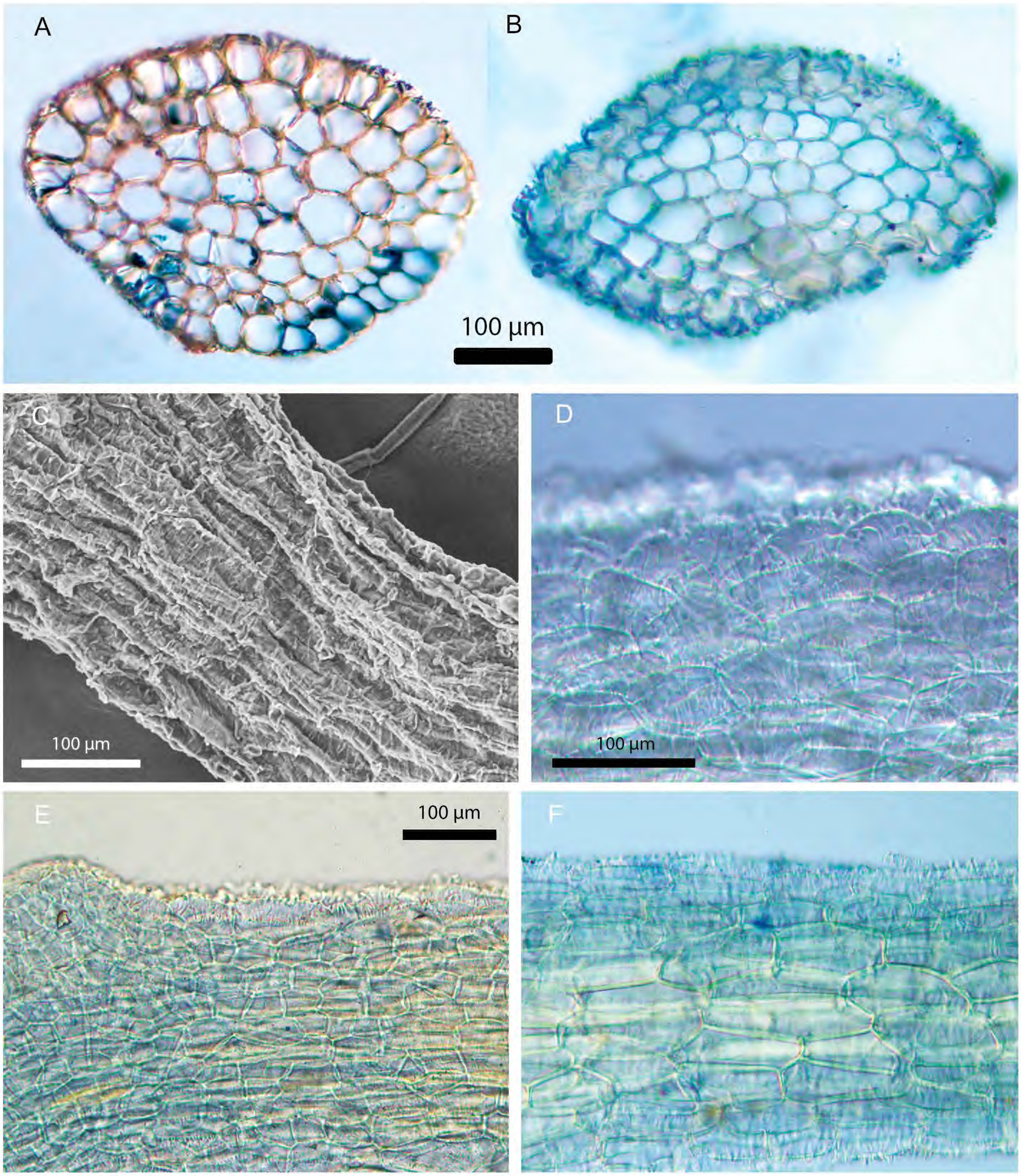

Fig. 3. *Riccardia dimorpha*. A, B. Transverse sections of main axis from female and male plants showing a lack of dimorphism in the main axis dimensions. A. Female, photographed from CHR 606646. B. Male, photographed from CHR 603443. C, D. Epidermis ornamentation. C. Dorsal epidermis, SEM view showing striations. D. Ventral epidermis, light microscope view. Both photographed from CHR 526319. E, F. Epidermal cells. E. Dorsal epidermis. F. Ventral epidermis and margin showing verrucose thickenings in side view. Both photographed from CHR 603443. 100 µm scale bar applies to E and F.

and equally frequent at any position on the main axis (Fig. 1). Gemmae absent. Main axis 280–500 µm wide between pinnae, 180–350 µm and (5)7–10 cells thick, subterete in transverse section, width to depth ratio 1.4–1.8:1, unwinged (Fig. 3A,B). Dorsal epidermal cells not smaller in transverse sectional view than internal cells. Ventral epidermal cells smaller in transverse sectional view than internal cells (typically 30–32 µm deep, not 37–39 µm deep as for internal cells). Epidermal cells sometimes mamillose 0.7 mm below the thallus apex (of main axis or branch) due to bulging of the outer cell wall. Epidermal surfaces with

transverse thickenings (striately verrucose) on both dorsal and ventral surfaces (Fig. 3B,C), the outer epidermal wall 4 µm thick, the thickenings 6 µm thick. All thallus cells chlorophyllose. Dorsal epidermal cells quadrate to elongated-rhomboid (2.2–7.0:1), 43–105 × (28)35–50 µm, 40–50 µm deep, the vertical cell walls 5 µm thick (Fig. 3E). In transverse section view, dorsal epidermal cells rectangular, taller than wide. Ventral epidermal cells hexagonal-elongate with acute cell ends (length to width ratio 2.0–4.0:1), 75–160 × 33–50 µm, 28–45 µm deep, the vertical cell walls near the thallus apices 2 µm thick but in older parts of the thallus 5 µm thick (Fig. 3F). In transverse section view ventral epidermal cells are isodiametric. In transverse section, internal rows of cells are equal in size to epidermal cells. Dorsal subepidermal cells 175–200 µm long, 52–63 µm wide, 40–48 µm deep. Cell walls in transverse sectional view all c. 4 µm thick and slightly thickened at the corners into concave-sided trigones. Oil-bodies invariably one in each dorsal epidermal cell, colourless, coarsely granular (botryoidal), mostly spherical (75%) and 8–16 µm diameter, less often ellipsoidal and 10–30 × 7–10 µm (Fig. 4). Endophytic mycorrhizae absent. Brown, granular, spherical inclusions 9–14 µm diameter occasionally present in 2 discontinuous rows 1–2 cells from the thallus margin and midway between dorsal and ventral epidermis, the inclusions equally present in main axis and branches (Fig. 5). Dioicous. Male and female plants usually separate but occasionally mixed. Male branches originating from main axis or from short side-branches facing obliquely dorsally, 800–1500 µm long, the fertile part 700–1400 µm long, 400 µm wide, a marginal wing present, the dorsal surface between the two wings narrow, sometimes with a sterile extension of the branch beyond the antheridia (Fig. 6A). Antheridia 3–8 per male branch. Antheridia 120 µm diameter, on a uniseriate stalk. Female branches solitary, on pinnae in the distal half of the plant, on a very short branch and facing dorsally, sessile, 500 µm long, with 2–8 archegonia in pairs, the gynoecium surrounded on its dorsal surface with many unbranched scales c. 400 µm and 8 cells long, 3 cells wide (Fig. 6C). Calyptra 1000 µm long, 320 µm diameter, cylindrical, the calyptra surface covered in projections that have a striate-verrucose surface, umbo absent. Sporophyte not seen.

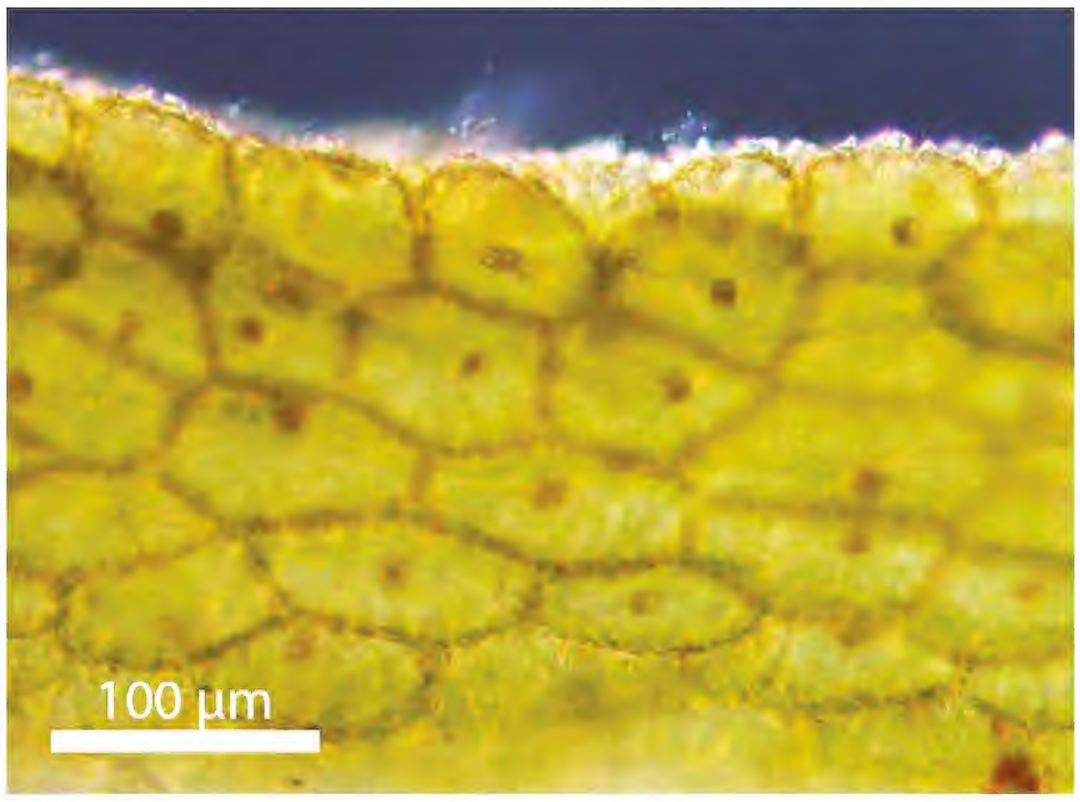

Fig. 4. *Riccardia dimorpha*, oil-body, one per cell in dorsal epidermis. Surface verrucae obscure the oil-bodies. Photographed from CHR 668241.

Diagnosis: *Riccardia dimorpha* is similar to *R. alcicornis* in that the main axis is subterete, 5–10 cells deep, with dark- and thick-walled cells in several internal layers of old parts of the main axis, and it has a pinnate to bipinnate branching style. Male branches are clam-like in being bilaterally compressed with two wings facing dorsally, and the dorsal branch surface is narrow. It differs from *R. alcicornis* in being dioicous and in having strong transverse striations on the epidermal cell walls, in male and female plants differing in plant length and richness of branching, with female plants being shorter and with more branches per plant than male plants.

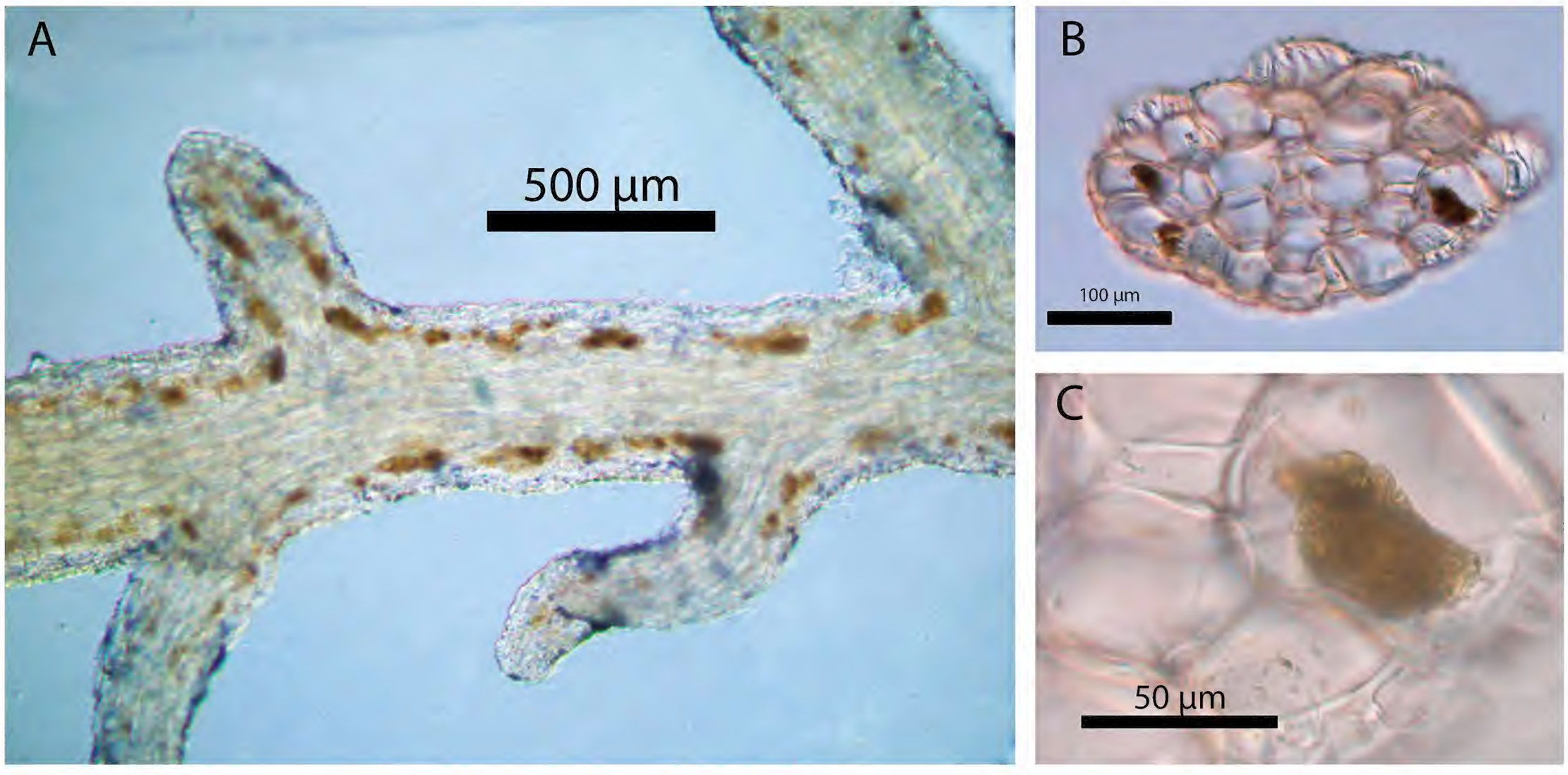

Fig. 5. *Riccardia dimorpha*, brown cellular inclusions. A. Dorsal view of main axis and branches showing discontinuous lines of inclusions. B. Cross-section of a thallus branch showing three brown cellular inclusions. C. A single cellular inclusion. A–C photographed from CHR 668200.

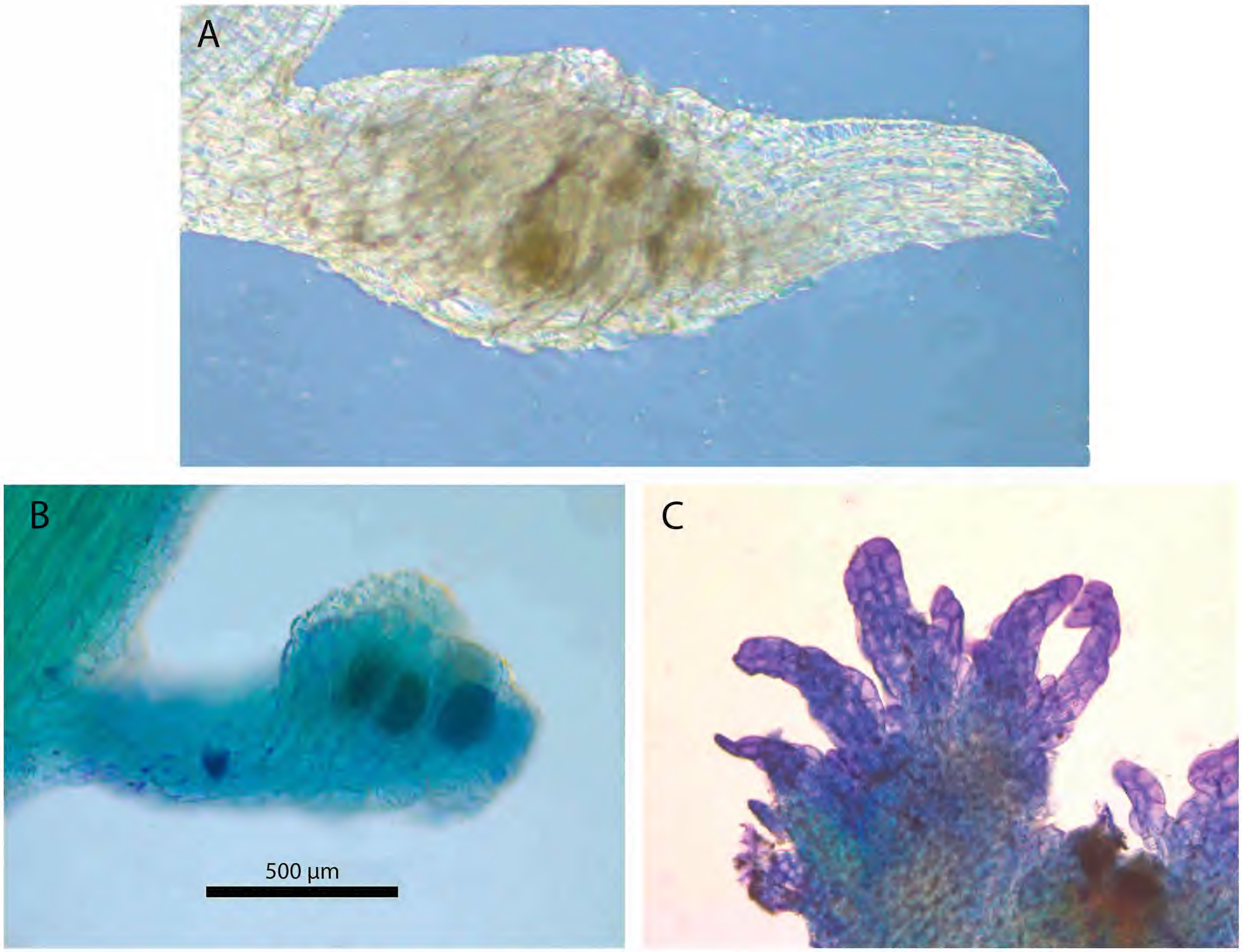

Fig. 6. *Riccardia dimorpha*. A, B. Male branches. C. Female branch. A photographed from CHR 603443, B from CHR 518930, C from CHR 409780. Scale bar applies to A–C.

Distribution: Endemic to New Zealand; South Island (35–700 m), Stewart Island / Rakiura (215–305 m). Known from Western Nelson (Stockton Plateau, Mt Frederick, Mt William Range, Te Kuha Ridge, terrace east of Nine Mile Road east of Westport, Tōtara River, Tiropahi River), Westland (Cascade Plateau), Fiordland (Mt Burns), and Stewart Island / Rakiura (Deceit Peaks, Magog).

Ecology: The species is nearly always found in low-stature *Leptospermum scoparium* shrublands and openings in *Leptospermum scoparium* scrub, where the vascular species between the shrubs are *Chionochloa juncea*, *Empodisma minus*, *Gleichenia microcarpa*, *G. dicarpa*, *Gahnia rigida*, and *Machaerina teretifolia*. This vegetation is known in New Zealand as pakihi (Mew 1983) and is on flat or low-angled terrain. Soils are gleyed podzols with impeded drainage, resulting in the sites being shallowly inundated by frequent rain. The plants are usually on humic soil formed from the *Leptospermum* and peat-forming monocots. Pakihi results from burning in historical times of tall podocarp forests in which *Dacrydium cupressinum* was the main tree species. *Leptospermum scoparium* scrub develops if the vegetation is not repeatedly burnt, but deliberate burning is commonly done by deer and pig hunters to maintain open habitat. Many of the plant species of pakihi, both vascular and non-vascular, are fire-adapted. Pakihi in southern Stewart Island / Rakiura (Magog and Deceit Peaks) is very similar in composition and fire history to pakihi in Western Nelson Ecological Province.

One collection, from Te Kuha Ridge, is from *Lepidothamnus intermedius – Fuscospora cliffortioides* forest 8 m high. This may have been the common habitat of the species on the Stockton and Denniston plateaux, Mt William, and the Orikaka River before forests were burnt in the historical period.

At Bird's Ferry, Tōtara River, *Riccardia dimorpha* occurs on an old, raised beach surface in *Leptospermum scoparium / Machaerina teretifolia – Gleichenia dicarpa* fern rushland that has nearby intact forest of *Dacrydium cupressinum*, *Dacrycarpus dacrydioides*, *Metrosideros robusta*, *Fuscospora cliffortioides*, and *Lophozonia menziesii*. At this pakihi, *Goebelobryum vermiculare*, *Lethocolea squamata*, and *Riccardia crassa* are accompanying species (Fig 7).

Fig. 7. *Riccardia dimorpha*, habitat, growing in bryophyte 'stalactites'. The vascular plant present growing on the stalactites is *Forstera mackayi* and other vascular plant species growing above the stalactites may also have roots in the stalactites. Stockton Plateau. CHR 606646.

At Stockton Plateau and Mt Frederick, the species was interwoven through other small thread-like bryophytes such as *Acromastigum anisostomum*, *Telaranea inaequalis*, and *Zoopsis* in hanging bryophyte 'stalactites', which are kept constantly moist by water seepage from sloping sandstone pavements above the overhangs. These stalactites of bryophytes also contain roots of flowering plants such as *Forstera mackayi*, and are a distinctive feature of the incised streams of the plateau (Fig. 8).

Borland Bog in eastern Fiordland is a raised mire in which *Leptospermum scoparium*, *Empodisma minus*, and *Sphagnum cristatum* are the dominant species (Mark et al. 1979). The bog does not appear to result from historical burning of forest, but most of the *Leptospermum* has been burnt repeatedly (Mark et al. 1979).

Etymology: The epithet 'dimorpha' refers to the difference between male and female plants in secondary sexual characteristics, namely plant length and number of meristems (shoot tips) per plant. The difference among sexes is such that, with familiarity, it is often possible to correctly predict the sex of an individual before reproductive structures are observed.

Conservation status: The species was neither formally nor informally recognised at the time of the most recent threatened plant listing (de Lange et al. 2020). A status of 'not threatened' is recommended as the species is widely distributed on the western side of the South Island and on Stewart Island / Rakiura and is commonly found in *Riccardia* specimens from pakihi.

Specimens examined: NEW ZEALAND: Western Nelson: Mangatini Stream, 540 m, 171.893°E, 41.653°S, on 4 m-high rock wall at back of overhang kept wet by seepage, associated with *Ceramanus tuberifera*, *Kurzia hippuroides*, *Lepidozia spinosissima*, *Leucobryum javense*, *Neolepidozia patentissima*, *Psiloclada clandestina*, *Rhizogonium pennatum*, *Riccardia cochleata*, *Telaranea inaequalis*, and *Tetracymbaliella decipiens*, female, 13 Sept 2005, *D. Glenny 9611* (CHR 573608); Mangatini Stream, 330 m, 171.918°E, 41.628°S, on soil over rock overhang with hanging bryophyte stalactites, on stream bank, *Metrosideros umbellata – Lepidothamnus intermedius – Dacrydium cupressinum / Phormium tenax / Gahnia rigida – Empodisma minus – Gleichenia microphylla* scrub 5 m tall, with *Acromastigum anisostomum*, *Kurzia hippuroides*, *Psiloclada clandestina*, and *Telaranea inaequalis*, male, 15 Sept 2005, *D. Glenny 9662* (CHR 580023); southern slopes of Mt Frederick, Deep Creek, 550 m, 171.836°E, 41.745°S, on bryophyte stalactites on vertical rock wall dangling almost into pool of water, female, 28 Jan 2009, *D. Glenny 10578* (CHR 606646); Stockton Plateau, north of T31 Stream, 670 m, 171.888°E, 41.666°S, *Leptospermum*

Fig. 8. *Riccardia dimorpha* female plant habit, with *Goebelobryum vermiculare* and *R. crassa*, Birds Ferry pakihi. CHR 668200.

scoparium – Chionochloa juncea – Metrosideros umbellata – Phormium cookianum shrubland on sandstone pavement, male, 16 Dec 2010, *D. Glenny 11096* (CHR 618714); Denniston Plateau, Waimangaroa River, 680 m, 171.787°E, 41.763°S, on peat soil in *Leptospermum scoparium* shrubland 10 cm tall, female, 20 Mar 2019, *D. Glenny 14579 & M. Renner* (CHR 657812, NSW, F). Westport, pakihi east of Nine Mile Road, 110 m, 171.658°E, 41.799°S, *Gahnia rigida – Gleichenia dicarpa* fern rushland on terrace, with *Kurzia calcarata* and *Lethocolea pansa*, female, 19 Jan 1996, *D. Glenny 6313* (CHR 509835); Stockton Plateau, Cypress Stream, 700 m, 171.881°E, 41.706°S, hummock and pool system on terrace, male and female, 27 Nov 1998, *D. Glenny 7579b* (CHR 518930); Orikaka River, 345 m, 171.966982°E, 41.732°S, *Leptospermum scoparium – Epacris pauciflora* shrubland, on soil with *Telaranea herzogii*, male, 23 Oct 2004, *T. Hay s.n.* (CHR 583069); Mt William Range, 688 m, 171.910°E, 41.687°S, 50 cm tall *Leptospermum scoparium* shrubland on sandstone pavement, with *Chionochloa juncea*, female, 14 Dec 2010, *D. Glenny 11104* (CHR 618720); Te Kuha Ridge, 600 m, 171.684°E, 41.812°S, *Leptospermum scoparium* 50 cm high / *Gleichenia microcarpa + Empodisma minus* sedge shrubland, on peat soil, female, 19 Mar 2001, *D. Glenny 8416* CHR 526319);T e Kuha Ridge, 600 m, 171.684°E, 41.812°S, *Lepidothamnus intermedius – Fuscospora cliffortioides* forest 8 m tall, with *Acromastigum cavifolium, Neolepidozia tetradactyla, Riccardia crassa,* and *Zoopsis setulosa*, female, 19 Mar 2001, *D. Glenny 8466* (CHR 526368); Westport, pakihi east of Nine Mile Road, 120 m, 171.644°E, 41.800°S, [*Leptospermum scoparium*] / *Machaerina teretifolia – Gleichenia dicarpa* fern rushland, with *Drosera spathulata, Goebelobryum vermiculare*, *Lycopodiella diffusa*, female, 10 March 2020, *D. Glenny 14750 & K. Frogley* (CHR 668241, F); Charleston, 171.436E, 41.935°S, 150 m, sparse *Gahnia rigida - Gleichenia microphylla / Lycopodiella diffusa* sedgeland on terrace, female and male, 19 Feb 2000, *D. Glenny 8150* (CHR 527490);Tōtara River, Birds Ferry Road, 35 m, 171.490°E, 41.860°S, [*Leptospermum scoparium*] / *Gahnia rigida – Gleichenia inclusisora* fern rushland, with *Riccardia alcicornis*, female, 30 May 2020, *D. Glenny 14825a* (CHR 668258, F); Tōtara River, Birds Ferry Road, 35 m, 171.490°E, 41.860°S, [*Leptospermum scoparium*] / *Machaerina teretifolia – Gleichenia dicarpa* fern rushland, with *Goebelobryum vermiculare*, *Kurzia hippuroides, Lycopodiella diffusa*, *Riccardia multicorpora,* and *Telaranea herzogii*, female, 1 June 2020, *D. Glenny 14832* (CHR 668200, F); Tōtara River, Birds Ferry Road, 35 m, 171.490°E, 41.860°S, *Leptospermum scoparium* / *Machaerina teretifolia – Gleichenia inclusisora* fern rushland, female, 31 May 2020, *D. Glenny 14833* (CHR 668267, F); Tōtara River, Birds Ferry Road, 35 m, 171.490°E, 41.860°S, *Leptospermum scoparium* / *Machaerina teretifolia – Gleichenia inclusisora* fern rushland, female, 30 May 2020, *D. Glenny 14827* (CHR 668267); Tiropahi River, 145 m, 171.464°E, 41.977°S, *Leptospermum scoparium / Gahnia rigida – Gleichenia dicarpa* / *Riccardia crassa* fern rushland, female, 31 May 2015, *D. Glenny 12899b* (CHR 638186, STU); Tiropahi River, 136 m, 171.422°E, 41.953°S, *Leptospermum scoparium / Machaerina teretifolia – Gleichenia dicarpa / Riccardia crassa* fern rushland, on soil, female, 31 May 2015, *D. Glenny 12889a* (CHR 638171); **Westland:** Cascade Plateau, Donald Creek, 250 m, 168.433°E, 44.023°S, [*Leptospermum scoparium – Halocarpus bidwillii*] / *Gleichenia – Empodisma minus* rushland, with *Riccardia crassa* and *R. multicorpora*, female, 29 Jan 2018, *H. Speight s.n.* (CHR 684781); **Fiordland:** Borland Bog, 200 m, c. 167.553°E, 45.787°S, growing in *Sphagnum cristatum*, male, 10 Jan 1984, *J. Child H5175* (CHR 409759); **Stewart Island / Rakiura:** SW of Deceit Peaks, 167.655°E, 47.091°E, 305 m, *Leptospermum scoparium – Lepidothamnus intermedius – Halocarpus biformis* shrubland, on soil, with *Lycopodiella diffusa* and *Telaranea herzogii*, female, 20 March 2005, *N. Zviagina s.n.* (CHR 503818); Magog, 215 m, 167.575°E, 47.189°S, opening in *Leptospermum scoparium* scrub, with *Acromastigum anisostomum*, *A. cavifolium, A. mooreanum*, *Clasmatocolea notophylla*, *Riccardia pusilla*, *Tetracymbaliella decipiens*, *Telaranea inaequalis*, and *Trichotemnoma corrugatum*, male, 10 Jan 2005, *D. Glenny 9332* (CHR 574651).

Discussion

Comparison with similar New Zealand species

A strongly striately verrucose epidermis is shared with *Riccardia crassa* and *R. perspicua*. *Riccardia dimorpha* is easily distinguished from those two species by its much narrower thallus. In addition, *R. intercellula* E.A.Brown and *R. browniae* have a lightly striately verrucose surface. All five are compared in Table 1. The two most notable differences between *R. dimorpha* and the other four species are, firstly its narrow thallus with almost no overlap with the minimum main axis width of the other four species, and secondly, *R. dimorpha* is dioicous while of the other four, only *R. crassa* is dioicous. *Riccardia dimorpha* is easily distinguished from *R. crassa* on thallus width.

Table 1. Comparison of *Riccardia dimorpha* with other New Zealand species that have a striately verrucose epidermis. Data from Brown and Braggins (1989), supplemented with author's observations.

	R. dimorpha	*R. perspicua*	*R. crassa*	*R. intercellula*	*R. browniae*
plant length (mm)	10–18	10–15	15–45	7–10	5–17
thallus width (µm)	250–320	(400)500–3700	960–2250	570–810	300–1000
thallus depth (µm)	180–340	85–117	147–860	147–177	105–295
thallus cell row depth	5–10	5–6	4–15	6	(4)5–9(10)
epidermis cell contents	chlorophyllose	echlorophyllose in older parts of thallus	chlorophyllose	echlorophyllose	chlorophyllose
slime papillae length × width (µm)	35–45 × 25	80–150 × 20–33	97–450 x 21–63	100–200 × 16–25	100–140(230) × 15–33
slime papilla persistence	usually not persisting	not persisting	persisting	persisting	persisting
slime papilla position	ventral only	ventral only	ventral only	ventral and dorsal	ventral only
slime papilla ornamentation	smooth	smooth	striately verrucose	smooth	smooth
ectomycorrhizae	absent	present within ventral epidermal cells, scattered in dorsal epidermis and subepidermis	absent	present, between ventral cells	present in ventral epidermal and subepidermal cells
epidermal ornamentation	strongly striately verrucose	strongly striately verrucose and castellate	strongly striate	very lightly striate	lightly striate
sexuality	dioicous	monoicous	dioecious, rarely monoicous	monoicous	monoicous

New Zealand has four species belonging to sect. *Alcicornia*: *Riccardia alcicornis*, *R. furtiva* E.A.Br. & Braggins, *R. umida* E.A.Br., and *R. multicorpora* E.A.Br. (Brown and Braggins 1989). They are compared in Table 2. Mostly notably, *R. dimorpha* is the only species of the five that has striately verrucose epidermal ornamentation.

Riccardia dimorpha is similar to *R. alcicornis* in that the main axis is subterete, with dark-brown- and thick-walled cells in several inner cell layers in older parts of the main axis, and the branching is pinnate to bipinnate (see Brown and Braggins 1989: Fig 4:1 and 4:2). The male branches are very similar in being bilaterally compressed so that the dorsal face is in a groove between the lateral wings (see illustrations in Brown and Braggins 1989: Fig. 4:12; and Hässel de Menendez 1972: Fig. 7j). The mucilage papillae of both species are shortly clavate. *Riccardia dimorpha* differs from *R. alcicornis* in being dioicous and in having strong epidermal cell ornamentation. The ventral epidermal cells of *R. dimorpha* are hexagonal-elongate with a length to width ratio of 2.0–4.0:1, while those of *R. alcicornis* are less elongate (length to width ratio 1.1–1.7:1).

The key to New Zealand species in Brown and Braggins (1989: 20–25) can accommodate *Riccardia dimorpha* by modifying couplet 13 and adding a new couplet before their couplet 14:

13 Monoicous, epidermis lightly striately verrucose, endomycorrhizae present ..... *R. browniae*

13 Dioicous, epidermis strongly striately verrucose, endomycorrhizae absent ..... 13′

13′ Main axis flattened, 960–2250 µm wide; slime papillae 100–230 µm long, papilla surface striate ..... *R. crassa*

13′ Main axis subterete, 250–320 µm wide; slime papillae 35–45 µm long, papilla surface smooth ..... *R. dimorpha*

Table 2. Comparison of *R. dimorpha* with New Zealand species of *Riccardia* sect. *Alcicornia*. Data from Brown and Braggins (1989).

	R. dimorpha	*R. alcicornis*	*R. furtiva*	*R. umida*	*R. multicorpora*
sexual dimorphism	present	absent	absent	unknown	absent
main axis width (µm)	280–500	190–590	141–366	225–310	255–446
main axis depth (µm)	180–340	185–260	90–268	110–155	177–215
main axis cell depth	5–10	10–15	7–13	7–8	9–11
epidermal ornamentation	striately verrucose	smooth	smooth	smooth	smooth
ectomycorrhiza	absent	absent or present	present or absent	present	present in lower 3–4 layers
sexuality	dioicous	monoicous	monoicous	dioicous	dioicous
slime papilla length (µm)	35–45	40	25	18–170	40 × 20

Dimorphism

Patches of female plants of *Riccardia dimorpha* were more than twice as common as patches of male plants. Female-biased sex ratios in dioecious species of bryophytes are common (Longton and Schuster 1983) but not universal (McLetchie and Puterbaugh 2000).

Female plants of *Riccardia dimorpha* had more meristematic tips than male plants. This has also been observed in *Marchantia inflexa* Nees & Mont., where female plants have greater meristematic tip production than males (McLetchie and Puterbaugh 2000). They reported that "Females grew faster, produced more meristematic tips and had lower levels of asexual reproduction than males. Number of meristematic tips was negatively correlated with asexual reproduction and positively correlated with growth rate. These sex-specific patterns may lead to the high frequency of single sex patches as well as biased adult population sex ratios that are observed in the field."

Riccardia dimorpha has male plants less branched than female plants, in accord with the Patagonian species *Riccardia longioleata* and with Furuki's (1991) observation. However, the male plants of *R. dimorpha* and *R. longioleata* are longer than female plants contrary to Furuki's observation of sexual dimorphism in *R. pusilla* Grolle) and *R. marginata* var. *pacifica*, in which the males were dwarfed.

Relationships with extra-territorial species

Riccardia dimorpha belongs in *Riccardia* subg. *Riccardia* sect. *Alcicornia* Hässel (Hässel de Menendez 1972), which is defined as having a thallus filamentous, biconvex, semi-terete, 120–160 µm wide (width to depth ratio 1.0–2.5:1), without ribs or wings. In southern South America there are five species in section *Alcicornia* (Hässel de Menendez 1972): *R. fuscobrunnea* (Steph.) A.Evans, *R. corralensis* (Steph.) A.Evans, *R. conimitra* (Steph.) A.Evans, *R. longioleata* Hässel, and *R. alcicornis* (Hook.f. & Taylor) Trevis, which are compared to *R. dimorpha* in Table 3. None of these South American species have a striately verrucose epidermis. One species, *R. fuscobrunnea*, has an ectomycorrhiza present.

Table 3. Comparison of *Riccardia dimorpha* with southern South American species of *Riccardia* sect. *Alcicornia*. Data on South American species from Hässel de Menendez (1972).

	R. dimorpha	*R. alcicornis*	*R. fuscobrunnea*	*R. corralensis*	*R. longioleata*	*R. conimitra*
sexual dimorphism	present	absent	absent?	absent?	present	absent?
main axis width (µm)	280–500	120–260	252–324	540–1000	240–624	180–600
main axis depth (µm)	180–340	130–190	160–200	168–204	168–257	156–204
main axis cell depth	5–10	8–11	6–8	6–7	5–6	5–8
epidermal ornamentation	striately verrucose	absent	absent	absent	absent	absent
ectomycorrhiza	absent	absent	present	absent	absent	absent
sexuality	dioicous	monoicous	dioicous	dioicous	dioicous	dioicous
slime papilla length (µm)	35–45	19–24	31–35	36–48	24–45	24–36

Hewson's (1970) revision of Australian and New Guinean *Riccardia* preceded Hässel de Menendez's (1970) publication of the name sect. *Alcicornia* Hässel. However, Australia has *Riccardia alcicornis*, type of the section, and *R. geniana* Hewson (Hewson 1970) of Papua New Guinea probably also belongs in the section. *Riccardia geniana* has a smooth epidermis. *Riccardia pindauensis* Hewson of Mt Wilhelm, Papua New Guinea, has a "cuticle armed with fine dentition" (Hewson 1970: 78) but has a main axis only 3–6 cells deep, not (5–)7–10 cells deep as in *R. dimorpha*.

In summary, comparison with species of New Zealand, southern South America, Australia, and New Guinea shows that it is unlikely that *Riccardia dimorpha* has been previously described.

The description of *Riccardia* sect. *Alcicornia* can be expanded with these characters: surface ornamentation striately verrucose (in *R. dimorpha* only), sexuality usually dioicous (monoicous in two of ten species).

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References

Brown EA, Braggins JE (1989) A revision of the genus *Riccardia* S.F.Gray in New Zealand with notes on the genus *Aneura* Dum. *Journal of the Hattori Botanical Laboratory* 66: 1–132. DOI

de Lange PJ, Glenny D, Frogley K, Renner MAM, von Konrat M, Engel JJ, Reeb C, Rolfe JR (2020) *Conservation status of New Zealand hornworts and liverworts, 2020*. New Zealand Threat Classification Series 31. (Department of Conservation: Wellington) PDF

Delph LF (1999) Sexual dimorphism in life history. Pp. 149–173 in Geber MA, Dawson TE, Delph LF (eds) *Gender and sexual dimorphism in flowering plants*. (Springer: Berlin) DOI

Engel JJ, Glenny D (2008) *A flora of the liverworts and hornworts of New Zealand. Vol. 1.* Monographs in Systematic Botany Volume 110. (Missouri Botanical Garden: St Louis) URL

Engel JJ, Glenny D (2019a) *A flora of the liverworts and hornworts of New Zealand. Vol. 2. Geocalycaceae, Brevianthaceae, Lophocoleaceae*. Monographs in Systematic Botany Volume 134. (Missouri Botanical Garden: St Louis)

Engel JJ, Glenny D (2019b) *A flora of the liverworts and hornworts of New Zealand. Vol. 3. Plagiochilaceae, Acrobolbaceae, Schistochilaceae, Balantiopsidaceae to Lepidolaenaceae*. Monographs in Systematic Botany Volume 135. (Missouri Botanical Garden: St Louis)

Furuki T (1991) A taxonomical revision of the Aneuraceae (Hepaticae) of Japan. *Journal of the Hattori Botanical Laboratory* 70: 293–397. DOI

Grolle R (1966) Miscellanea hepaticologica 61–70. *Journal of Japanese Botany* 41(8): 225–232. DOI

Hagborg A, Söderström, L (2022) Notes on early land plants today 80. *Riccardia browniae*, a new name for *Riccardia pusilla* (Steph.) E.A.Br., hom. illeg. *Lindbergia* 45(01152): 1. DOI

Hässel de Menendez GC (1972) Revision taxonomic del genero *Riccardia* (Hepaticae). Especies Andinopatigonicas y Subantarcticas incluyendo las islas Juan Fernandez, Malvinas, Georgias del Sur, etc. *Revista del Museo Argentino de Ciencias Naturalis "Bernadino Rivadavia"*, *Botànica* 4: 1–242.

Hedenäs L, Bisang I (2011) The overlooked dwarf males in mosses – unique among green land plants. *Perspectives in Plant Ecology Evolution and Systematics* 13: 121–135. DOI

Hewson HJ (1970) The family Aneuraceae in Australia and New Guinea. II. The genus *Riccardia*. *Proceedings of the Linnean Society of New South Wales* 95: 60–121. URL

Lloyd DG, Webb CJ (1977) Secondary sex characters in plants. *Botanical Review* 43(2): 177–216. DOI

Mark AF, Rawson G, Wilson JB (1979) Vegetation of a lowland raised mire in eastern Fiordland, New Zealand. *New Zealand Journal of Ecology* 2: 1–10. URL

McLetchie DN, Puterbaugh MN (2000) Population sex ratios, sex-specific clonal traits and tradeoffs among these traits in the liverwort *Marchantia inflexa*. *Oikos* 90(2): 227–237. DOI

Mew G (1983) Application of the term "pakihi" in New Zealand – a review. *Journal of the Royal Society of New Zealand* 13: 175–198. DOI

Mizutani M, Hattori S (1957) An etude on the systematics of Japanese *Riccardias*. *Journal of the Hattori Botanical Laboratory* 18: 27–64. DOI

Reeb C, Bardat J (2014) Studies on African *Riccardia* types and related material. *Cryptogamie, Bryologie* 35(1): 47–75. DOI

Rico G. RR (2011) Methods for cell clearing and rehydration in thalloid liverworts. *Tropical Bryology* 33: 12–18. DOI

Schuster RM (1992) *The Hepaticae and Anthocerotae of North America, East of the Hundredth Meridian. Vol. VI*. (Field Museum: Chicago)

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The fruiting body of *Treubia tasmanica* (Marchantiophyta: Treubiaceae)

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Abstract

Sporophytes of *Treubia tasmanica* R.M.Schust. & G.A.M.Scott, newly discovered in 2021, differ in several ways from what is generally accepted as 'normal' for liverworts. The seta is chlorophyllose, slow growing and persists after spore dispersal. While in growth the sporophyte is positively phototropic, and responsive to changes in light orientation on timescales of hours. There is some evidence the seta goes into senescence before expiring. The opened capsule valves are capable of closing in adverse weather and subsequently re-opening under dry conditions. These discoveries call for some revision of the assumption that all liverwort capsule valves are mere passive actors in the life of sporophytes once dehisced.

Introduction

The small genus *Treubia* K.I.Goebel (Marchantiophyta: Treubiaceae) includes around 10 species and is represented in Tasmania by two: *T. lacunosa* (Colenso) Prosk., and *T. tasmanica* R.M.Schust. & G.A.M.Scott. Meagher (2008) stated that *Treubia tasmanica* was previously known also from Victoria but may now be confined to Tasmania since the two formerly known populations in Victoria were destroyed some years ago by earthworks. However, he reported the presence of populations in the West Tyers in 2015, so the species may still be extant in that state (D. Meagher, pers. comm.). In Tasmania the species is apparently widespread near Lake St. Clair, at the southern end of the Cradle Mountain – Lake St. Clair National Park (D. Meagher, pers. comm.), but there are remnant populations elsewhere on the island, including on the Blue Tier in the State's northeast.

Meagher and Fuhrer (2003) wrote: 'As far as we know, sporophytes have never been found.' However, fruiting specimens have since been collected by Neville Scarlett in the West Tyers site in 2006 (D.C.Cargill, pers. comm.). Collections in the Tasmanian Herbarium (HO) do not include sporophytes. The species has now been collected with sporophytes on the Blue Tier. A detailed description and notes are appended here.

Schuster and Scott (1969) extensively described the gametophyte of *T. tasmanica*. This paper mainly describes the novel finding and development of the unusual sporophyte.

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Materials and methods

Observations with photographic records were made on the same population over three seasons: there were three records between 11–17 November 2021, 54 records between 21 September and 24 November 2022 and 10 records between 8 May and 19 July 2023. Time lapse images taken over that period demonstrate previously unrecorded observations of sporophyte development in this species.

A specimen collected in mid-November of 2021 included several plants sporting three still erect setae with dehisced capsules and a single developing sporophyte. The plants were growing on a well-trodden track over plant litter in semi-permanent shade in degraded cool-temperate rainforest (Fig. 1). Accompanying bryophytes were *Chiloscyphus* sp., *Gackstroemia weindorferi* (Herzog) Grolle, *Lepidozia* sp., and *Lepicolea scolopendra* (Hook.) Dumort. ex Trevis. The specimen was collected on a tray and kept under cover in the shade for drying as a herbarium specimen. No attempt was made to keep it alive, but the substrate composed of organic debris was sufficiently moist to keep the plants alive for several days and permitted some observation of growth before desiccating. Glenny *et al*. (2015) state 'In *Treubia*, the mucilage is exuded from clefts in the ventral thallus and swells dramatically when it absorbs water. It may function for water storage …'. Although the authors had not included *T. tasmanica* in their study, this phenomenon has also been observed in the species under discussion and may further explain why the specimen was able to remain turgid for several days under dry conditions.

Fig. 1. *Treubia tasmanica* sporophytes showing the deep green colour of developing setae and the gradual change to hyaline (photo by A. McLennan).

On 30 October of 2022 a small section of thallus with a well-developed calyptra was brought indoors and stored in a closed jar near a window to observe development (Fig. 7C, D). Only distilled water was provided to keep it from desiccating.

Field images were taken with a Canon G12 camera. Some images were taken by Andy McLennan with an Olympus TG-6 camera which depict more vivid colours. Micrographs were taken with a Canon 1000D camera on an unbranded compound microscope from China, with subjects mounted in water. The spore image was stacked using Hugin software. Limited sampling was done because of scarce available material.

2021 Results and Discussion

Sporophyte and its development

The 25 mm long seta of a sporophyte emerging from the calyptra took four days to reach 58 mm in length before dehiscence of the capsule. The age of the sporophyte when collected was not known.

The single capsule measured was short-ellipsoidal, 2.6 mm wide and 2.8 mm long. This is considerably larger than the capsule of *Treubia lacunosa* described by Schuster and Scott (1969) at 2 mm wide and 2.4–2.5 mm long. It consisted of four valves which folded back to release spores and elaters. The elaters

Fig. 2. *Treubia tasmanica*. A. Green seta with mature capsule. B. Dehisced capsule with elaters (photo by A. McLennan). C. Seta trans-section showing hollow centre with broken cells in the inner perimeter. D. Hyaline detached seta near calyptra (photo by A. McLennan).

are bi-spiral and long, around 850 × 9 µm (Fig. 3B), falling within the dimensions of *T. lacunosa* elaters given by Schuster and Scott (1969) as 500–1000 µm long and 5–8 µm wide. The spores (Fig. 3A) are around 28 µm in diameter and appear to contain chloroplasts.

The capsule wall of *Treubia lacunosa* was described as normally 3-stratose (occasionally with 2–4 layers), around 80–85 µm thick, although sometimes up to 95–105 µm. Cells of the middle layer are 17–24(–26) µm radially and 16–18(–24) µm tangentially. Cells of the innermost layer are considerably smaller than cells of the outer epidermal layer which have the 'capsule-wall layer of strongly bulging, convex cells' (Fig. 4D; Schuster and Scott, 1969).

The *Treubia tasmanica* capsule wall was so distinct from that of *T. lacunosa* that examination of a transverse section would suffice as a key distinguishing factor. In contrast to *T. lacunosa*, the capsule of *T. tasmanica* has valves of 6–8 cell strata with walls that are colourless and *c.* 155 µm thick (Fig. 4C). There is no obvious bulging of outer cells, but they did have a thicker epidermal layer. In transverse section, the outer cells ranged from 25–67 µm wide tangentially, and 28–40 µm deep radially. Mid-layer cells ranged from 50–72 µm tangentially and 14–26 µm radially. It was impossible to determine size of inner cells because they appeared squashed and deformed, possibly from the pressure exerted by developing spores, but cells close to the inner wall measured up to 87 µm tangentially. In capsule wall cells of *T. lacunosa*, the radial dimension is generally greater than that of the tangential, but it is the reverse in *T. tasmanica*.

The elaters of *Treubia tasmanica* did not all scatter from the capsule upon dehiscence; some persisted at the tip of the seta (Fig. 2B) which remains erect for several days. They did not appear to be attached to the capsule valves but were clustered in an unorganised manner at the tip as well as lower down on the setae. Similar clustering of elaters around dehisced capsules has been observed in *Symphyogyna hymenophyllum* (Hook.) Nees & Mont. which has connate valve tips.

The seta of *Treubia tasmanica* tapers from *c.* 1.2 to 1.1 mm in diameter and reaches 60 mm in length. In cross-section the seta consists of around 440 cells. The seta was hollow (Fig. 2C) for most of the length, but the distal few mm of the same was solid. When one decapitated seta preserved in ethanol was placed on a slide, the ethanol evaporated permitting ingress of air from both ends. A few drops of water were added to prevent dehydration and this sealed the bubbles of air. It was then possible to push a bubble from one end of the seta to the other by applying pressure progressively with the handle of a scalpel.

Duckett and Pressel (2017: Fig. 2e) show a central 'fluid-filled lysigenous cavity' in the seta of *Treubia lacunosa*. The same was observed in *T. tasmanica* (Fig. 3D). Epidermal cells of the setae are considerably smaller than the inner cells which measure around 70µm. The setae remained erect for four days or more following capsule dehiscence before desiccating. Striations on the dehisced setae on the left and right margins (Fig. 1) are cross-walls, not surface ornamentation.

The seta of *Treubia tasmanica*, on emergence from the calyptra, is a rich green, fading slightly as it lengthens (Fig. 2A at full extension and Fig. 5A), remains green-tinged for several days after dehiscence of the capsule before becoming hyaline (Fig. 2D). Setae at different stages of maturity are visible in Fig. 1.

A peculiarity of the *Treubia tasmanica* setae is that unlike those of other liverworts, e.g. Lepidoziaceae, they do not collapse in their entirety and shrink after capsule dehiscence, but dry out slowly from the distal region while the basal part remains turgid. One possible explanation for this difference is that liquid stops flowing across the transfer cells in Lepidoziaceae once setae attain maximum height but not in *T. tasmanica*.

The discovery of living plants of *T. tasmanica* with emerging sporophytes allowed their growth to be monitored over several days. *Treubia tasmanica* is not unique in having green chloroplast containing setae, but the prevalence and significance of this seems to have been largely overlooked in recent years. Availability of fresh material enables the capsule cell walls to be characterised (Fig. 4). The only on-line image of a living *T. lacunosa* sporophyte taken from a New Zealand specimen (Fig. 5C) shows the seta to be a shade of green, not hyaline. Similarly, an image of the same in a developing sporophyte is green in Glime (2021: Fig. 111). It had been assumed, but not established, that the young green seta would turn hyaline upon elongation. Hassel de Menendez (1994) says of *T. scapanioides* R.M.Schust. that the seta had 'hyaline thickened outer walls, inner cells hyaline but thin-walled' but makes no mention of cell contents, but as her study was of dried herbarium specimens, she made no mention of cell contents. Schuster and Konstantinova (1995) write of *Apotreubia hortonae* R.M.Schust. & Konstant. ex Konstant.: 'Seta 510–550 µm in diam., chlorophyllose to time of maturation of spores.' This presumably refers to the state where the sporophyte is ready to emerge from the calyptra, but there is no mention of what happens subsequently.

A recent paper by Patino *et al.* (2022: Fig. 3C) depicts mature sporophytes of *Monoclea forsteri* Hook. with indisputably green setae up to the time of dehiscence. Likewise, Pant *et al.* (2023: Fig. 1E–G) describe the newly rediscovered *Sewardiella tuberifera* Kash. from India as 'seta dull green' and depict green setae. There may be other liverworts elsewhere in the world that exhibit similar characteristics to *Treubia tasmanica* that are also worthy of further observation in the field.

Schuster (1984) noted a 'capsule with massive, chlorophyllose seta' for *Haplomitrium* and that *Symphyogyna, Pallavicinia* and *Hymenophytum* (all Pallaviciniaceae) also shared this feature. That both early diverging clades share this characteristic suggests that chlorophyllose setae could be the ancestral form from which the modern, short-lived, hyaline setae evolved.

Size of setae has no bearing on their chlorophyllose nature. *Chandonathus squarrosus* (Menzies ex Hook.) Mitt. and *Adelanthus falcatus* (Hook.) Mitt., among others, are described as having 'massive' setae with no mention of them being chlorophyllose (Engel and Glenny 2008).

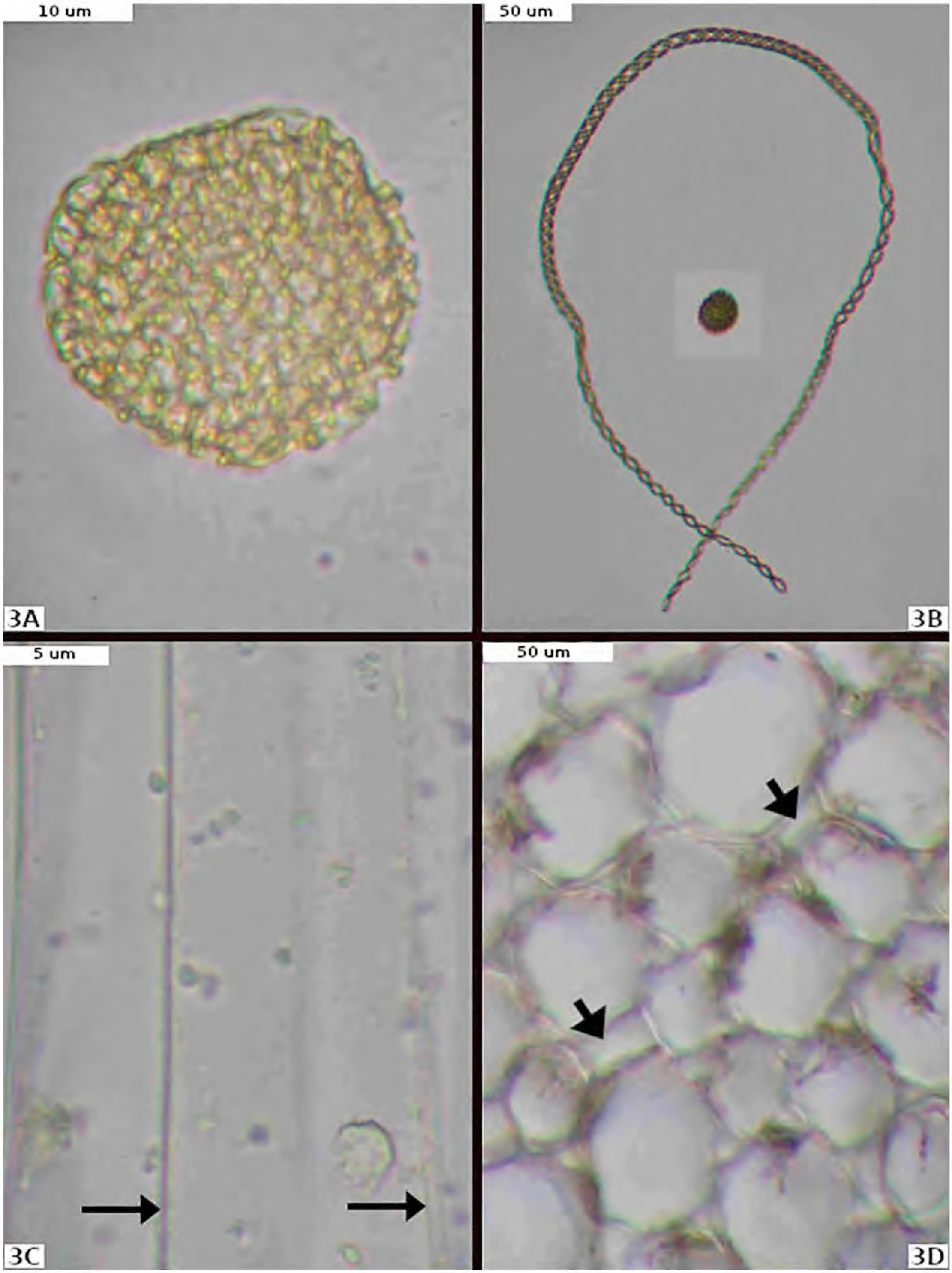

Fig. 3. *Treubia tasmanica*. A. Spore. B. Bi-spiral elater with inserted spore at same scale. C. Cell contents, walls arrowed. D. Schizogenous intercellular spaces (ICS) arrowed.

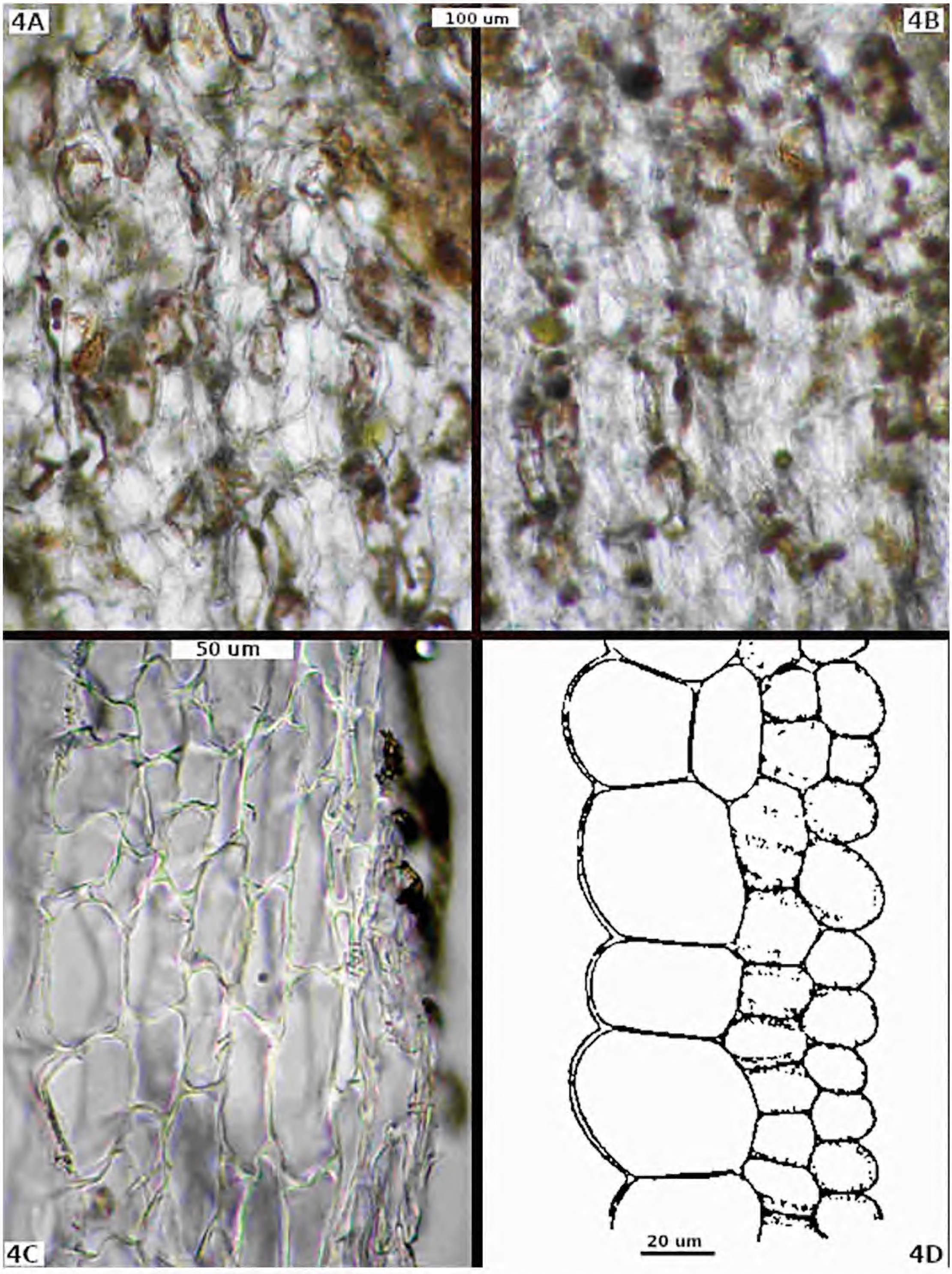

Fig. 4. *Treubia tasmanica* (A–C) and *T. lacunosa* (D). *T. tasmanica*: A. Capsule external wall. B. Capsule inner wall. C. Capsule wall transverse section. *T. lacunosa*: D. Capsule wall transverse section, republished from Schuster and Scott (1969) with permission from Hattori Botanical Laboratory.

Fig. 5. A. Young sporophyte of *Treubia tasmanica* (photo by A. McLennan). B. Sporophyte of *Goebelobryum unguiculatum* (photo by Phil Collier). C. Sporophyte of *T. lacunosa* (photo by S. Kerr from http://www.kaimaibush.co.nz/index.html). D. Dehisced sporophyte of *Pallavicinia rubristipa* (photo by A. McLennan).

If the seta's only function is to elevate the sporangia for spore dispersal, there needs to be some explanation why some persist erect for several days after capsule dehiscence. *Pallavicinia rubristipa* Schiffn. has been observed to have sporophytes taking several days to attain full extension after they emerge from the calyptra, then remaining erect for several days after dehiscing. High humidity may be ruled out as a factor since conditions under which they were stored under cover were considerably dryer than would normally prevail in their habitat in shaded rain forest. Plants of *Treubia tasmanica* described here were growing amongst Lepidoziaceae species which all had setae that mostly collapsed by early afternoon.

While it is not invariably the case that persistent setae are always chlorophyllose, it is yet to be determined if green setae always persist beyond a few hours of emerging from the perianth or shoot calyptra. *Goebelobryum unguiculatum* (Hook.f. & Taylor) Grolle had hyaline seta that persisted over several days, and possibly over two weeks (Fig. 5B) before collapsing. Initial observations indicated that it opened and closed two slits in the capsule, presumably to disperse spores when conditions were propitious. Sporophytes collected at the end of the fruiting season in early June were reported to have hardly any spores left in the capsule.

A *Chiloscyphus* sp. observed fruiting in mid-Autumn 2023 had sporophytes that took varying lengths of time to attain full setae height after capsules first fully emerged from the perianth. One isolated sporophyte that was probably several days old when first recorded took seven days to attain full height and achieve dehiscence, and it remained upright for at least another three days before collapsing.

The mechanism for fluid movement in seta cells as they elongate relies upon the schizogenous intercellular spaces (ICSs) found in 'taxa with large fleshy setae …' (Duckett and Pressel (2017: Fig. 2g) (see Fig. 3D). Duckett and Pressel (2017) go on to state that 'In liverwort setae ICSs are most likely a key structural component maintaining and augmenting the hydrostatic skeleton solely determined by the turgidity of its constituent thin-walled cells'. They state further: 'the elongated setae in several genera including members of the Haplomitriopsida (*Treubia*), Marchantiopsida (*Monoclea*), Fossombroniales (*Allisonia*) and Jungermanniales (*Wettsteinia*) contain central fluid-filled lysigenous cavities with the remains of broken cells around their periphery' (Fig. 2C). These central cavities may also play a part in the translocation of fluid and solutes within the setae.

While there are open channels for translocation of fluid within the seta there are no such pathways across the placental walls. This is effected through transfer cells, which are not only prevalent across the plant kingdom, but extend to algae and fungi as well. There is a considerable body of literature on the origins and function of transfer cells found on one or both sides of the placental wall in nourishing the sporophyte (Ligrone and Gambardella 1988; Offler *et al.* 2002; Carafa *et al.* 2003). Ligrone and Gambardella (1988) speculate that 'The persistence of sporophyte transfer cells may account for the sporophyte ability to uptake the water necessary for the elongation of the seta after spore maturation'. The prevailing view expressed recently is that 'In this intergenerational zone, specialized cells facilitate an intensified flow of solutes to the sporophyte that is dependent on the persistent gametophyte' (Henry and Renzaglia 2021). Transfer cells consist of membranes, not unidirectional valves, so there is no reason why the flow could not reverse.

2022–3 Observations and Discussion

The same population of *Treubia tasmanica* observed above came into fruit again the following two seasons and provided an opportunity to record sporophyte development over an extended period. Calyptra appeared as well-developed, prominent, spherical protuberances on thalli (Fig. 6A) when first observed on 21 September 2022. Judging from photographs, there was no perceptible increase in diameter over a period of nine weeks until capsules emerged, but as no observations were made of calyptra height, growth might have occurred over that time without being noticed. There was considerable size difference between the largest calyptra and the smallest, but this was not due to maturity as the capsule from a smaller calyptra emerged two days earlier than that of the larger. The capsule on the right in Fig. 6C was about 30% wider than that on the left.

No measurements were taken in the field in 2022 but a few calyptra were observed in the same population in mid-May of 2023 and one was measured having a diameter of *c.* 1.2 mm. This grew to 1.8 mm five weeks later. There was a mishap with the main sporophyte that was being monitored (emergent capsule in Fig. 6B). Rain over several days caused the tip to droop over until the capsule touched the ground. Nevertheless, the seta remained partially green at the base and did not shrivel to the base until 24 November 2022.

A summary of development based upon the exposed capsule in Fig. 6B follows:

- the entire capsule had emerged from calyptra on October 31, but the seta was not visible;
- it took six days for the seta to attain maximum height (Fig. 6C), on November 6, before the capsule began dehiscing the following day (Fig. 6D);
- the seta remained upright for another seven days, until November 14, when it started drooping;
- the green seta with dehisced capsule slowly faded to hyaline over another ten days (Fig. 7B, arrowed), before it shrivelled to the base on November 24, giving it a life of 23 days.

Schuster's (1984) explanation of the capsule dehiscing mechanism was that upon exposure to the atmosphere the outer cells dry out and the valves shrink transversely thus setting up forces that rupture the vertical sutures. The developing sporophyte of *Treubia tasmanica* collected the first season was stored under conditions much drier than found in its natural habitat yet failed to dehisce until the seta was fully extended four days later. In the second season it took seven days for the emergent capsule to dehisce (Figs. 6B, 6C and 6D). Weather conditions were near perfect with warm sunny days. Other bryophytes in the vicinity, mainly Lepidoziaceae and *Chiloscyphus* sp., had sporophytes dehiscing by mid-day every day during this period.

Fig. 6. *Treubia tasmanica*. A. First observation of enlarged calyptra on 21 September 2022. B. Capsule emerged from calyptra on 31 October 2022. C. Seta attained maximum height on 6 November 2022. D. Capsule dehisced on 7 November 2022.

Fig. 7. *Treubia tasmanica*, 2022. A. Capsule valves closed to protect elaters and spores in damp weather, 12 November (insert is a different sporophyte observed on 18 November). B. Arrowed seta faded to hyaline before shrivelling on 23 November. C. Capsule emerging from calyptra grown indoors on 31 October. D. Sporophyte grown indoors. i) 2 November; ii) 5 November (seta attains maximum height of 34 mm); iii) top: Capsule dehisced on 6 November; bottom: Capsule valves closed on 7 November.

However, drying of the capsule wall in *Treubia tasmanica* could not be excluded as one of the factors influencing dehiscing. The sporophyte kept indoors was taken out of the closed container and exposed to the atmosphere six days after the capsule had emerged (Fig. 7Dii). It promptly dehisced quarter of an hour later, after which it was returned to the humidity of the closed jar. A peculiarity of *Treubia tasmanica* is its ability to close the capsule valves under moist conditions. Figure 7Diii shows the start of dehiscing (top) but a day later the valves had closed (bottom).

The situation in the field was no less remarkable. It had rained overnight and part of the morning on November 12. The fuzzy setae apex that was present the previous day had disappeared and in their place were entire capsules, a little deformed but nevertheless fully enclosing residual elaters and spores (Fig. 7A). The shiny appearance suggests water had filled the capsules and was encapsulated. It is possibly the weight of this water that caused the tall sporophyte to droop. Photo insert shows a different sporophyte from November 18 which shows no such shininess. They remained this way for four days, but the anticipated reopening of capsules was not observed. When the weather turned dry, the capsule valves had shrivelled, exposing some elaters, but not in the quantities present earlier.

The sporophyte taken indoors was phototrophic. It was possible to change the inclination by twisting the jar to face different directions.

The change in seta colour as it lengthens is particularly interesting. Garjeanne (1932) cites an experiment by Du Buy and Nurnbergk (1932) on *Pellia epiphylla* (L.) Corda which showed that seta growth took place mainly at the proximal end. If this were the case for *T. tasmanica* there ought to be a colour gradient from the base to the tip, but this is not so. Setae lengthen not by cell division but by cell elongation. In Figs. 6C, 6D and 7D the colour lightens as the seta lengthens suggesting the cells were expanding uniformly and the chloroplasts were diffusing into larger volumes.

It is at least a plausible hypothesis that the seta nourishes the sporangia during the brief period between emergence and dehiscing. It is not implausible that the spores grow in size during this period, which could explain the internal pressure needed to stress the capsule walls to the point they would burst open under dry conditions. The presence of apparently compressed cells in the inner capsule wall (Fig. 4C) would support this supposition.

Why the green seta remains attached to the gametophyte after the sporangia dehisces, and slowly fades to hyaline over a fortnight, is a thorny problem. In the absence of competing alternatives one possibility is that they are going into senescence where the chloroplasts transform into solutes which flow back into the gametophyte.

Our current understanding holds that young setae of at least some species of liverworts in compressed form are green. Schuster (1984) made passing reference to this: 'Prior to elongation, cells may seem strikingly chlorophyllose ...' but does not amplify on the subject. Puri (2011) stated that 'The cells of the immature foot and seta, the wall of the capsule and the elaters (of *Marchantia polymorpha* L.) contain chloroplast ...'. It is reasonable to question if the function of these chloroplasts is to provide nutrition to the developing sporophytes or if they are merely remnants of once functional organelles that have outlived their purpose. If the first case holds, several questions then arise (D.C. Cargill, pers. comm.): What is the process that nourishes the sporophyte after it emerges from the calyptra/perianth? Is it provided solely by the seta, or does it also receive nourishment from the gametophyte? Does the flow of nutrients stop upon the capsule dehiscing or is there a reverse flow into the parent?.

While the contribution of the seta to nourishing the gametophyte, if established, may be small it is not negligible. Some of the *Treubia* sporophytes were emerging from thalli that were hidden by overgrowth of other more vigorous bryophytes and grasses so even a brief period of photosynthesis may help keep the plants alive for another season.

Since *Treubia tasmanica* setae do not wilt for around two weeks after they are fully extended, it follows that the gametophyte has to continue pumping water across the transfer cells to keep the setae turgid. The hollow liquid filled central cavity of the seta, which extends almost to the top, simplifies matters. Fig. 7Dii shows water droplets adhering to the seta kept in a jar. On the assumption that condensation was more likely to have formed on the glass jar subject to temperature fluctuations, this is probably water from guttation. However, this has to remain conjecture for the present.

Renzaglia *et al.* (2007) summarised some widely held dogmas thus: 'Liverwort sporophytes remain enclosed within gametophytic tissue until the spores are mature. Sporangia are then elevated solely by rapid elongation of seta cells acting as a hydrostatic skeleton. The seta is ephemeral, lacks internal differentiation and is completely intolerant to desiccation.'

Treubia tasmanica appears to provide an exception to the rule. The claim that spores mature within the gametophyte is at least questionable. It has been reported that '*Fossombronia* capsules that have been elevated upon elongated setae may still have immature spores' (D.C. Cargill, pers. comm.). These spores were extracted from emerged capsules that had yet to dehisce. The seta is (relatively) slow growing, chlorophyllose and (semi)persistent. Puri (2011) wrote that 'In some sporogonia of *P(ellia) epiphylla*, the seta increases in length from 1 millimeter to as much as 80 millimeters in three to four days.' It is surprising that this extended life of sporophytes is not more widely known, since the book was first published in 1980. There are reasonable grounds for believing that the seta plays a part in nourishing the sporangia during the final days of maturity.

This paper is a first attempt to try and explain unusual phenomena and it is possible that wrong inferences may have been drawn. They are presented as the best interpretations available in the face of incomplete knowledge. Apart from the species discussed here, as well as *P. epiphylla*, it remains to be seen if other taxa with chlorophyllose setae mentioned by Schuster (1984), the Treubiales and *Monoclea forsteri* likewise have semi-persistent setae which remain erect after capsules dehisce and spores disperse. Morphological characteristics not previously published for *Treubia tasmanica* are presented below.

Taxonomy

Treubia tasmanica R.M.Schust. & G.A.M.Scott, *J. Hattori Bot. Lab.* 32: 248, figs 1(1–5), 2(5), 4(2), 5(1–5) (1969). *Type*: Tasmania: near Camp Creek, along Lyell Highway, west of Derwent Bridge, Surprise Valley, on slopes of Mt Arrowsmith, *R.M.Schuster 50376* (Holotype: F C0172296F).

Treubia insignis Goebel *sensu* Rodway, *Pap. Proc. R. Soc. Tasmania* 20 (1916).

Discovery of a second fruiting population in 2023 (CANB 999918) permitted study of the gametophyte, which had not previously been observed for *Treubia tasmanica*. This was growing on a sloping rock surface covered with organic debris. Accompanying bryophytes were *Lepidozia procera* Mitt., *Gackstroemia weindorferi* (Herzog) Grolle, *Wijkia extenuata* (Brid.) H.A.Crum and a *Bazzania* sp.

Basal parts of many plants were e-chlorophyllose but were still alive judging from mucilage below the axis. They were mostly under 25 mm in length. Vigorous plants measured up to 10.5 mm across the leaves, a little wider than Schuster and Scott's (1969) description of 5–9 mm wide. Branching was sparse, but there were up to three lateral branches on the main shoots. In general, there appeared to be little contact between the ventral axes and the substrate, other than through the intermediary of mucilage. Some rhizoids were branched. Although most fruiting plants sported only a single sporophyte, a few had two.

When describing *Treubia tasmanica*, Schuster and Scott (1969) mentioned 'mucilage plentiful, colourless'. *Treubia* mucilage was studied in detail by Duckett *et al*. (2006) who examined live thalli of three New Zealand species (subsequently reduced to two – *T. lacunosa* and *T. pygmaea* – in Glenny *et al*. 2015). They reported that thalli not only produced copious amounts of mucilage, but were also capable of replenishing it if this was removed and the thalli was placed in water. The same was observed for *T. tasmanica* where plants collected after rain had a thick layer of mucilage, especially on newer growth, but mucilage was present along the whole ventral axes. This shrank when stored in a humid container, but grew again when immersed in water for several hours (Fig 9D).

Oil bodies were present in most but not all lateral leaf cells which tended to decrease in size from leaf median to border (Fig 8A). Most of the leaf cells contained solitary oil bodies (Fig. 8B) but a few had up to four. Examination of lateral leaves less than four hours after collection displayed oil bodies that had largely lost their integrity and appeared as amorphous blobs (Fig 8C). An explanation of this could be found in Schuster (1992) who stated that 'the high light intensity (and heat) transmitted and concentrated through the Abbe condenser of the light microscope results in rapid disintegration of the bounding membrane and release of the lipid droplets'. Dried specimens that had been re-hydrated showed lipid droplets occupying almost the entire cell lumen. The few cells devoid of oil bodies were densely packed with cylindrical chloroplasts (Fig 8D). The green background is the effect of superimposition over multistratose cells below.

Schuster and Scott (1969) state 'Scattered axial cells with oil-bodies 135–170 µm long × 45–80 µm wide, more or less filling the cells in which they occur' without specifying which part of the axis they were referring to. This averages out to 153 µm × 63 µm giving a ratio of 1:2.4, somewhat higher than the oil body of the lateral leaf (Fig 8B) which measures 32 × 21 µm with a ratio of 1:1.5. Oil bodies retaining integrity in the specimen examined do not fill the cell lumen but may provide that illusion when lipids spill from the membrane (Fig 8C). Oil bodies from the calyptra vary greatly. Those from the distal part surrounding the capsule are somewhat regular in shape (Fig. 8E) while those surrounding the setae are greatly elongated, to over 1:5.5 ratio (Fig 8F). Since these cells would have originated from a pre-elongated state, it may be assumed that the oil bodies were once more regular and elongated as the cells stretched in one direction.

Although the calyptra appears green, and there are a few chloroplasts in the cells, it is mostly clear. It is the young seta which provides the appearance of green colour. It is about 10 mm high and 2.9 mm wide. Radially it consists of 10–12 cells and is approximately 0.21 mm thick (Fig. 9B). This is comparable to Schuster and Scott's (1969) description of *T. lacunosa* with 'lower third of calyptra *ca*. 8–12 cells thick'. Although the sector depicted here shows no oil bodies, they were present, mainly in the outer layer of cells, but a few were observed in inner cells as well.

There is an apparent discrepancy in that the thickness of calyptra walls together with that of seta (admittedly measured on different plants) do not add up to calyptra width. A similar discrepancy may be found in *T. lacunosa* where the calyptra width averages about 3 mm and the seta is 0.7 mm thick (Glenny *et al*. 2015), which makes each wall 1.15 mm wide. This is considerably thicker than that of *T. tasmanica* with walls of 0.21 mm thickness. A possible explanation for this discrepancy in both cases could be that the compressed seta within the calyptra has greater girth than that of the emerged seta.

Specimens examined relevant to discussion

Treubia tasmanica: Poimena, Blue Tier, 100 m along Moon Valley Rim Circuit, 13 Nov. 2021, 41°11'54.24"S, 148°00'19.92"E, 761 m, *T. Thekathyil 301* (HO 615113); Poimena, Blue Tier, 2.9 km along bike trail to Weldborough, 23 October 2023, 41°11'28.38"S, 148°00'59.46"E 750 m, *T.Thekathyil 312A* (CANB 999918).

Pallavicinia rubristipa: Three Notches Track, Blue Tier, 30 m north of first bridge, 29 Nov. 2021, 41°11'13.62"S, 148°00'35.34"E, 722 m, *T. Thekathyil 302* (HO 615114).

Goebelobryum unguiculatum: Port Sorrell, 100 m NE of nearby house, 04 June 2014, 41°11'08.70"S, 146°32'42.06"E, 9 m, *T. Thekathyil 168* (HO 578885, CANB, CAS, F).

Chiloscyphus sp., Lottah, 100m east from end of Gould St. 20 Apr. 2023, 41°13'13.02"S, 148°01'27.24"E, 325 m, *T. Thekathyil 303* (HO 615115, CANB, CAS).

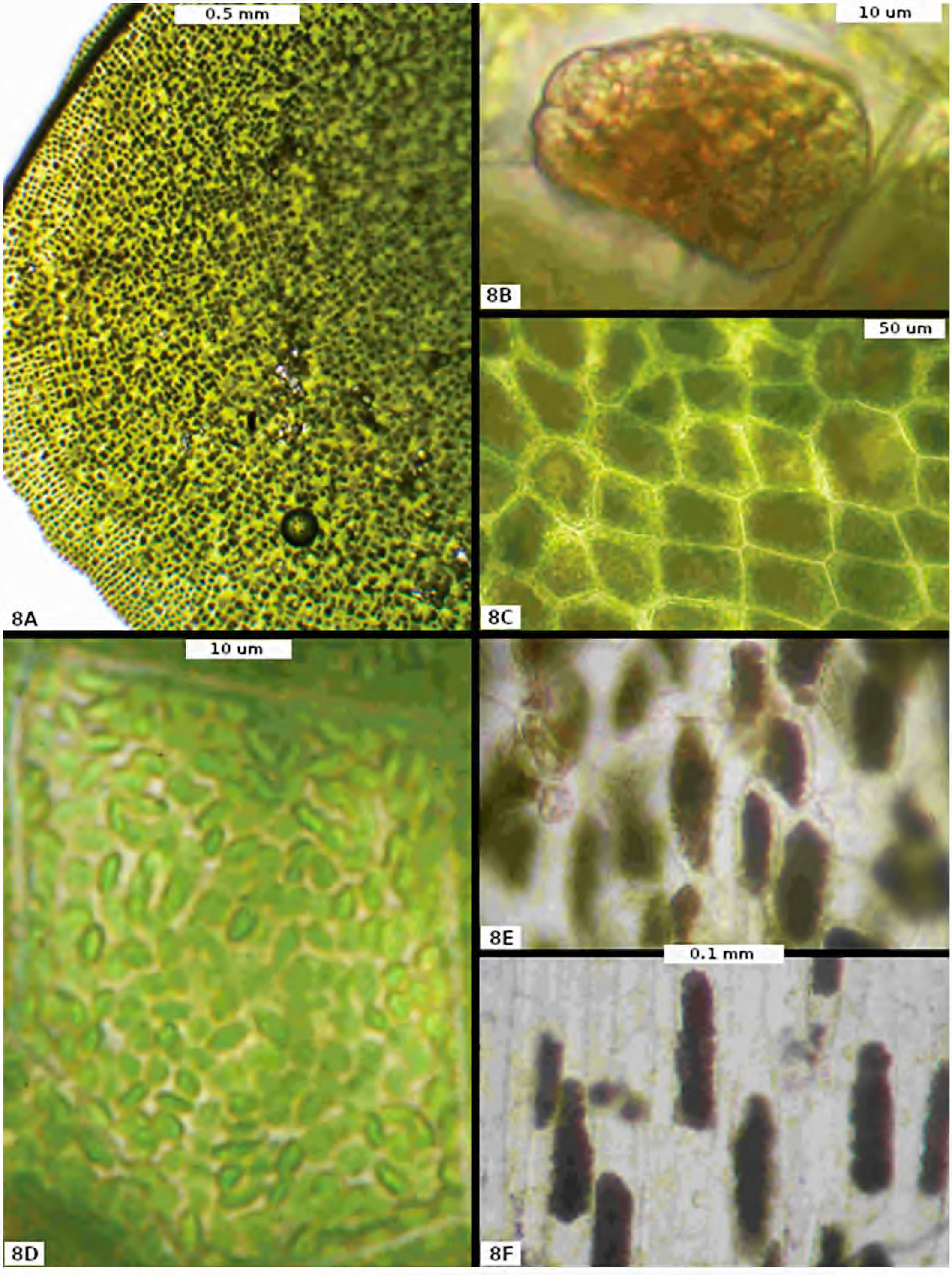

Fig. 8. *Treubia tasmanica* (CANB 999918 population). A. lateral leaf showing cell size decreasing towards border. B. Intact oil body. C. Oil bodies releasing lipid droplets into cell lumen. D. Chloroplasts in cell devoid of oil bodies. E. Oil bodies from upper region of calyptra covering capsule. F. Oil bodies stretched to fit elongating calyptra cells from lower region.

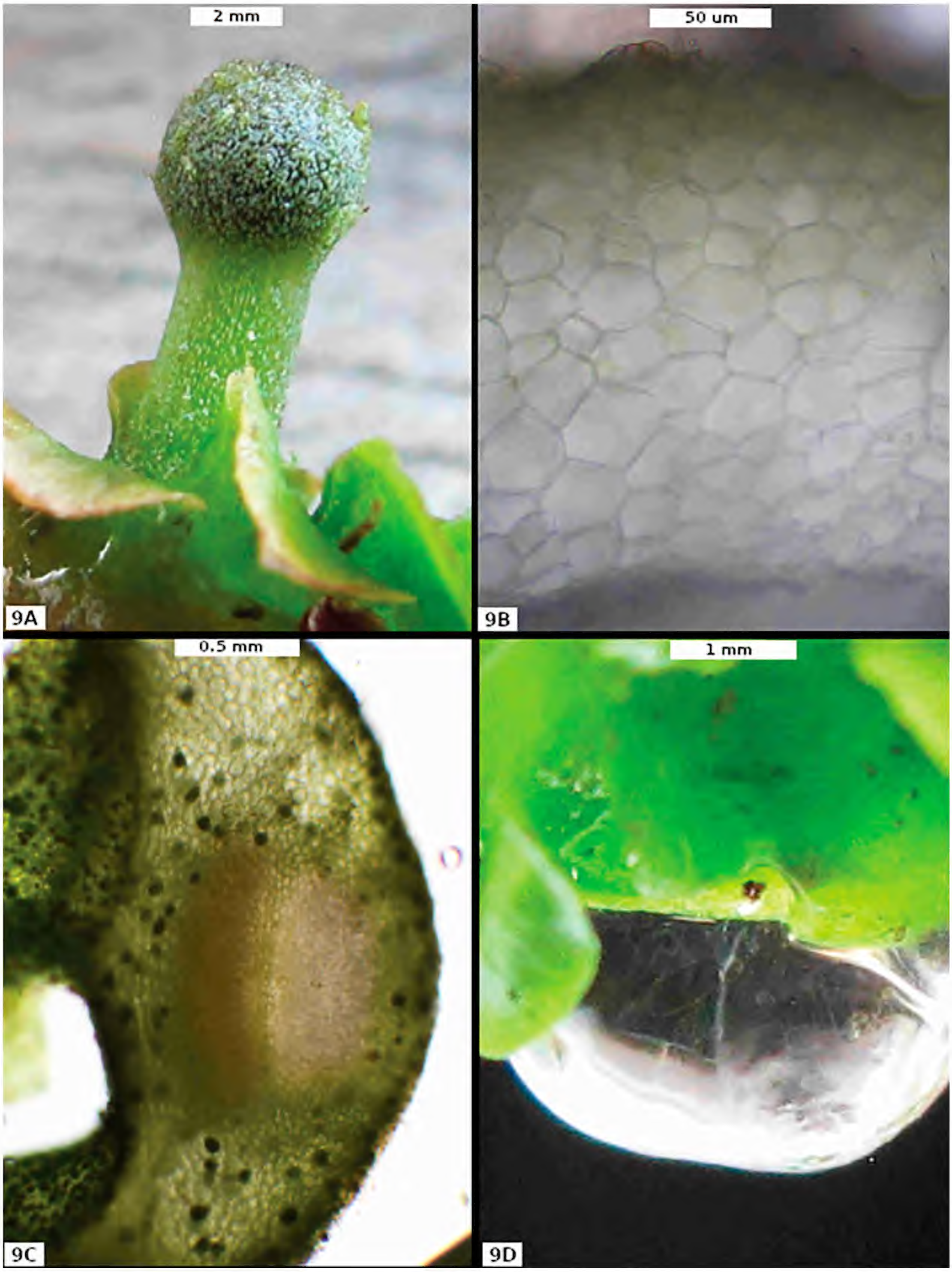

Fig. 9. *Treubia tasmanica* (CANB 999918 population): A. sporophyte ready to emerge from calyptra. B. Transverse section of calyptra wall. C. Transverse section of shoot axis showing scattered oil bodies. D. Mucilage below shoot axis after soaking in water.

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References

Carafa A, Duckett JG, Ligrone R (2003) The placenta in *Monoclea forsteri* Hook. and *Treubia lacunosa* (Col.) Prosk: insights into placental evolution in liverworts. *Annals of Botany* 92: 299–307. DOI

Du Buy HG, Nuernbergk E (1932) Phototropismus und wachstum der pflanzen. In von Frisch K, Goldschmidt R, Ruhland W, Winterstein H (eds), *Ergebnisse der Biologie*. Vol. 9. pp. 358–544. (Springer: Berlin, Heidelberg). DOI

Duckett JGD, Carafa A, Ligrone RO (2006) A highly differentiated glomeromycotean association with the mucilage-secreting, primitive antipodean liverwort *Treubia* (Treubiaceae): clues to the origins of mycorrhizas. *American Journal of Botany* 93(6): 797–813. DOI

Duckett JG, Pressel S (2017) The evolution of the stomatal apparatus: intercellular spaces and sporophyte water relations in bryophytes - two ignored dimensions *Philosophical Transactions of the Royal Society B* 373: 20160498. DOI

Engel JJ, Glenny D (2008) *A flora of the liverworts and hornworts of New Zealand:* Volume 1. (Missouri Botanical Gardens Press: St. Louis)

Garjeanne AJM (1932) Physiology. In Verdoon FR (ed), *Manual of bryology*. pp. 207–232. (Martinus Nijhoff: The Hague)

Glenny D, Bulman S, Temblay S (2015) Reassessment of *Treubia* species (Marchantiophyta: Treubiaceae) in New Zeealand. *Nova Hedwigia* 100: 355–372. DOI

Glime J (2021) *Bryophyte Ecology*. Volume 1 Figure 111. URL (Accessed 12 November 2021)

Henry JS, Renzaglia KS (2021) The placenta of *Physcomitrium patens*: transfer cell wall polymers compared across the three bryophyte groups. *Diversity* 13: 378. DOI

Hässel de Menéndez GG (1994) Patagonian bryophytes 12. On *Treubia scapanioides* Schust. *Journal of the Hattori Botanical Laboratory* 75: 237–242. DOI

Ligrone R, Gambardella R (1988) The ultrastructure of the sporophyte-gametophyte junction and its relationship to bryophyte evolution. *Journal of the Hattori Botanical Laboratory* 64: 187–196. DOI

Meagher D, Fuhrer B (2003) *A field guide to the mosses and allied plants of southern Australia*. Flora of Australia Supplementary Series, Number 20. (Australian Biological Resources Study/The Field Naturalists Club of Victoria: Canberra)

Meagher D (2008) Studies on Victorian bryophytes 8: The genus *Treubia* Goebel. *The Victorian Naturalist* 125: 36–38. URL

Offler CE, McCurdy DW, Patrick JW, Talbot MJ (2003) Transfer cells: cells specialized for a special purpose. *Annual Review of Plant Biology* 54: 431–454. DOI

Pant S, Tewari SD, Joshi P, Bhandari M, Arya R (2023). Rediscovery of *Sewardiella tuberifera* Kash., a long-lost monotypic endemic Indian liverwort. *Journal of Threatened Taxa* 15: 22726–22730. DOI

Patiño J, Bisang I, Goffinet B, Hedenäs L, McDaniel S, Pressel S, Stech M, Ah-Peng C, Bergamini A, Caners RT, Cargill DC, Cronberg N, Duckett J, Eppley S, Fenton NJ, Fisher K, González-Mancebo J, Hasebe M, Heinrichs J, Hylander K, Ignatov MS, Martínez-Abaigar J, Medina NG, Medina R, Quandt D, Rensing SA, Renzaglia K, Renner M, Ros RM, Schäfer-Verwimp A, Villarreal JC, Vanderpoorten A (2022) Unveiling the nature of a miniature world: a horizon scan of fundamental questions in bryology. *Journal of Bryology* 44: 1–34. DOI

Puri P (2011) *Bryophytes: morphology, growth and differentiation*. (Atma Ram and Sons: Delhi)

Renzaglia KS, Schuette S, Duff RJ, Ligrone R, Shaw RJ, Mishler BD and Duckett JG (2007) Bryophyte phylogeny: advancing the molecular and morphological frontiers. *The Bryologist* 110: 179–213. DOI

Schuster RM, Scott GAM (1969) A study of the family Treubiaceae (Hepaticae: Metzgeriales). *Journal of the Hattori Botanical Laboratory* 32: 219–268.

Schuster RM (1984) Evolution, phylogeny and classification of the Hepaticae. In Schuster RM (ed), *New manual of bryology*. Vol. 2. pp. 892–1070. (Hattori Botanical Laboratory: Japan)

Schuster RM (1992) The oil-bodies of the Hepaticae. 1. Introduction. *Journal of the Hattori Botanical Laboratory* 72: 151–162. DOI

Schuster RM, Konstantinova N (1995) Studies on Treubiales, I. On *Apotreubia* Hatt. et al. and *A. hortonae* Schust. and Konstantinova, sp. n. *Journal of the Hattori Botanical Laboratory* 78: 41–61. DOI

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Four new species of *Arthropodium* (Asparagaceae) from central and eastern Australia

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Abstract

Four species of *Arthropodium* R.Br. occurring in the Northern Territory, South Australia, Queensland, and New South Wales are newly described: *Arthropodium boreale* P.F.Horsfall & Jian Wang ter sp. nov., *Arthropodium glareosorum* P.F.Horsfall & Jian Wang ter sp. nov., *Arthropodium morganiae* P.F.Horsfall & Jian Wang ter sp. nov. and *Arthropodium sejunctum* P.F.Horsfall & Jian Wang ter sp. nov. The new species are illustrated and diagnosed against related species, their distributions mapped and a key to the new species provided.

Introduction

The genus *Arthropodium* R.Br. (Asparagaceae) was established by Brown (1810) and currently contains 13 species, predominantly Australian (eight species) with one extending to New Guinea, three in New Zealand, and one each in New Caledonia and Madagascar (CHAH 2024; POWO 2024; Wang & Horsfall 2024). Since the *Flora of Australia* (Brittan 1987a, b) there have been a number of changes to the taxonomy of Australian *Arthropodium*. These changes include one addition to the genus, *A. vanleeuwenii* S.J.Dillon (Dillon & Macfarlane 2020), the reinstatement of *A. pendulum* (Redouté) DC., (Redouté 1812; POWO 2024), and the transfer of *Dichopogon strictus* (R.Br.) Baker and *Dichopogon fimbriatus* (R.Br.) J.F.Macbr. to *Arthropodium* (Conran & Walsh 1994). Three informal species *Arthropodium* sp.1, VicFlora (2024) which equates to *A.* sp. Snowy River catchment (N.G.Walsh 6195), PlantNET (2024). *A.* sp. 2, VicFlora (2024) which equates to *A.* sp. South-east Highlands (N.G.Walsh 811), PlantNET (2024) and *A.* sp. 3, VicFlora (2024) which equates to *Arthropodium* sp. Albury (A.D.J.Piesse 9), PlantNET (2024) also occur, and are currently being reviewed. The family assignment of *Arthropodium* has also changed, i.e. Laxmanniaceae in APG II (2003), Asparagaceae in APG III (2009) and APG IV (2016). Fieldwork and a study of cultivated plants have resulted in the recognition of more new taxa. Four species, *A. boreale* P.F.Horsfall & Jian Wang ter, *A. glareosorum* P.F.Horsfall & Jian Wang ter, *A. morganiae* P.F.Horsfall & Jian Wang ter and *A. sejunctum* P.F.Horsfall & Jian Wang ter are described and compared to *A. strictum* R.Br., *A. milleflorum* (Redouté) J.F.Macbr. and *A. minus* R.Br. A distribution map for the four new species, a table of diagnostic characters and a key to the eight named species recognised in central and eastern Australia are also provided.

Horsfall PF, Wang J (2024) Four new species of *Arthropodium* (Asparagaceae) from central and eastern Australia. *Telopea* 27: 101–115. doi:10.7751/telopea18005

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Materials and methods

This study is based on observations of live material in the field and in cultivation, and the examination of dried herbarium specimens from AD, BRI, CANB, CNS, DNA, JCT, MEL, NSW, and NT. A dissecting microscope with a camera linked to a computer was used for accurate measurements and assessment of morphological characteristics on live and dried material. Measurements of roots, leaves, and inflorescences were made from dried herbarium material using a dissecting microscope and ruler. Root measurements are approximate as it can be difficult to determine an exact length of some divisions due to the tapering of fleshy necks and tubers. Measurements for the receptacle were obtained by removing both tepal whorls and measuring between the abscission zone at the pedicel apex to the ovary base. Receptacle widths have not been included. Flower dimensions are based on living plants, material reconstituted with boiling water or pressed specimens from the senior author's collection. Caudae have been measured from the adaxial side of the filament, from the inner surface where it meets the filament (where it can usually be observed), to the end of the hairs. Colours are based on fresh material. All photos were taken by the senior author, except where noted.

Character definitions

Roots: consist of the three major components. 1. The *corm*. 2. The *neck* which is between corm and the tuber and occurs in two main states, either with a *cortex* (fleshy), i.e. *A. glareosorum* and *A. sejunctum*, or *stele* (fibrous), i.e. *A. boreale*, *A. morganiae*, and either term maybe used. The neck section in the fibrous species often starts with a cortex which is ribbed and contractile, drawing the corm down to a sustainable level in the ground. This fleshy section then shrinks away as it matures (Fig. 8B). 3. *Tubers* occur at the distal end and are swollen components for storage (Dahlgren *et al*. 1985), and also act as anchors. True roots are also present, but they are not discussed in this paper and are not included in the measurements. They can grow from the corm, from the tuber base and adventitiously on tubers. Such roots are rarely seen on herbarium specimens, no doubt due to the difficulty of collection.

Tunic: the term is used for the persistent remains of the main nerves from the leaf sheath (Fig. 1). It is much looser in *Arthropodium* than those found in *Iridaceae*, which have a more clinging habit, but the function is the same. The tunic surrounds and acts as a protective barrier around the corm.

Shoots: s*ingle shoot* or *multiple shoots* have been observed for species in the field (sometimes differing from observations of cultivated specimens) and is used in this manuscript.

Bracts: are separated into three variations. *Leafy bracts* or *bracts* occurring along the scape. *Bracteoles* occur at the nodes along the branches and are small and less leafy and can have diagnostic shapes; these may be either dry or green. *Cataphylls* are a smaller, scarious bract-type primarily found on *Arthropodium* species with condensed cymules, at the base of the pedicels.

Cymules: the branches carrying the flowers have two forms. *Branched cymules* are elongated and generally have a single pedicel per node. *Condensed cymules* have multiple pedicels per branched node.

Fig. 1. Example of a tunic (remnant leaf nerves surrounding the corm) of *Arthropodium fimbriatum* R.Br. (Guyra, NSW) shown on an herbarium specimen. Voucher: *Bean 17276* (BRI).

Receptacle: the structure at the distal end of the pedicel and below the ovary, that seats the ovary, and holds the stamen and the tepals.

Connective: the material fusing the anthers together, possibly an extension of the filament (Fig. 4A).

Connective tissue: occurs along the filament margins from the base of the anthers and is adnate to them (Fig. 4A).

Caudae: the term 'tails' on *Arthropodium* has been applied by previous authors (Cheesman 1906; Conran *et al*. 1993; PlantNET 2024). These 'tails' are described here as *caudae* that are present on both sides of the filament margins, occurring either at the anther bases and adnate to both the anther base and filament margin, as shown by Stringer & Conran (1991: Fig. 1K) for *A. strictum*, or along the filament as on *A. glareosorum* . The caudae of *A. boreale*, *A. morganiae* and *A. sejunctum* are relatively obscure and rudimentary, but the connective tissue (including the hairs) extends shortly down the filament, with the caudae at the base (Fig. 4B). The caudae of *A. glareosorum* are distinct and occur further along the filament (Fig. 5B). The connective tissue between the filament and hairs is difficult to distinguish.

Capsule: dehiscence is loculicidal, splitting along the outer surface and centre of the locule, not from the septa.

Seed: of *Arthropodium* have not been discussed apart from length measurements. Seed testa have distinct patterning (Stringer *et al*. 1991), but a detailed study of the potential taxonomic significance of these patterns is beyond the scope of this paper.

Taxonomy

Arthropodium boreale P.F.Horsfall & Jian Wang ter, *sp. nov.*

Type: Queensland. North Kennedy District: Edwards Road and Hervey Range Road, Hervey Range. 20 February 2020, *P.F. Horsfall PFH4861* (holo: BRI [AQ1045612]).

Deciduous perennial herb, foliage erect, spreading, shoots multiple, plants loosely tufted to c. 10 cm diameter. *Roots* clumping, 3.5–19 cm long; *corm* growth is lateral, sequential, and branching; cortex neck thin in new growth and fibrous at maturity; *tubers* fusiform to turbinate, 14–25(–35) mm long, 6–10 mm wide. *Leaves* narrowly ensiform, 2–9 per shoot, 8–40(–55) cm long, 2–8(–10) mm wide, erect; *sheaths* canaliculate, clasping, edges smooth, white; *lamina* openly carinate, light green, adaxial surface smooth, abaxial surface with lightly raised nerves, lamina margin bullate, continuous, overlapping, slightly wavy (in plan view), ± with irregular minute asperities (Fig. 3A); *tunic*, none observed. *Inflorescence* 1 per shoot, 33–60(–80) cm long, scape 1.5–1.8 mm diameter, round in cross section, erect, 0–1 bracts before the 1st branch, branches 0–3, angular in cross section; subtended by narrow lanceolate *bracts* and reducing in size toward the apex; branched cymule nodes subtended by a lateral adpressed subulate *bracteole* with minute asperities on the edges toward the apex, becoming membranous toward the end of the branched cymule and with a scarious *cataphyll* subtending the pedicel (Fig. 3C), *pedicels* erect to slightly arcuate, 1, rarely 2 or 3 per node, divergent, held at *c.* 45–90°, 18–27 mm long, reducing in length toward the apex, becoming straight with flower pollination. *Flowers* semi-pendent to pendent, 20–25 mm diameter; *receptacle* 2.4–4 mm long, slightly nodding at anthesis, becoming erect in fruit; *tepals* dimorphic, recurved, outer tepals bicoloured, inner tepals concolorous; *outer tepals* narrow elliptic, 7–11.5 mm long, 2–4 mm wide, rib narrow, 3-veined, sometimes with 2 extra outer incomplete nerves, white to whitish-pink abaxially, pink to purple adaxially; *inner tepals* elliptic, 9–11.1 mm long, 3.8–7.5 mm wide, rib narrow, 3-veined, flanges exceeding the rib apex (notched), unevenly corrugated, edges ± finely erose to roughly dentate, pinkish-purple, rarely paler. *Stamen*: *filaments* sigmoid toward the apex, 3–4 mm long, straw yellow; *caudae*, residual; *hairs* dense, irregular lengths, abutting the base of the anthers and occurring down the filament, on connective tissue that is involute, leaving the adaxial side of

Fig. 2. *Arthropodium boreale* (Hervey Range, Qld, type location population). A. Flower and lateral bracteole. B. Different views of the stamen, T–B: Abaxial view showing the hairs. Adaxial view showing the open connective. Lateral view showing the apical pore of the anther and strongly sigmoid filament. C. Anther patterning on the lower theca. D. L–R: Outer tepal and inner tepal. E. Stigmatic papillae.

the filament bare and the margins and abaxial side covered (slightly elongated, cushion-like in appearance; Fig. 2B), apices glandular, bright yellow; *anthers* narrowly triangular, 3–3.8 mm long, tapering to the apex, pores flaring at the apex as the upper theca walls shrink back, pale purple to purple (rarely white), patterned with very fine forward-facing triangular, almost scale like pustules (Fig. 2C), diminishing toward the apex. *Pistil*: *ovary* globular, slightly lobed, 1–1.2 mm high, 1–1.3 mm wide, green; *ovules* 3, rarely 4 per locule; *style* 5.3–7.3 mm long, white to pale yellow, opaque at the ovary, turning to purple *c*. 2 mm toward the stigma; *stigma papillae* erect, tufted, 0.03–0.12 mm long, just exceeding the style width, apices glandular, purple, or white, opaque. *Capsule* globular, lobed, 3.25–6.3 mm high, 4–7.6 mm wide, loculicidal dehiscence, locule apices beaked, extending beyond the capsule apex, locules dehiscent for about half the capsule height, the base shrinking upon drying forcing the locules to spread apart (Fig. 3E). *Seed* 2–2.7 mm long, testa pustulate, black, shiny. Figures 2, 3, 4B (centre).

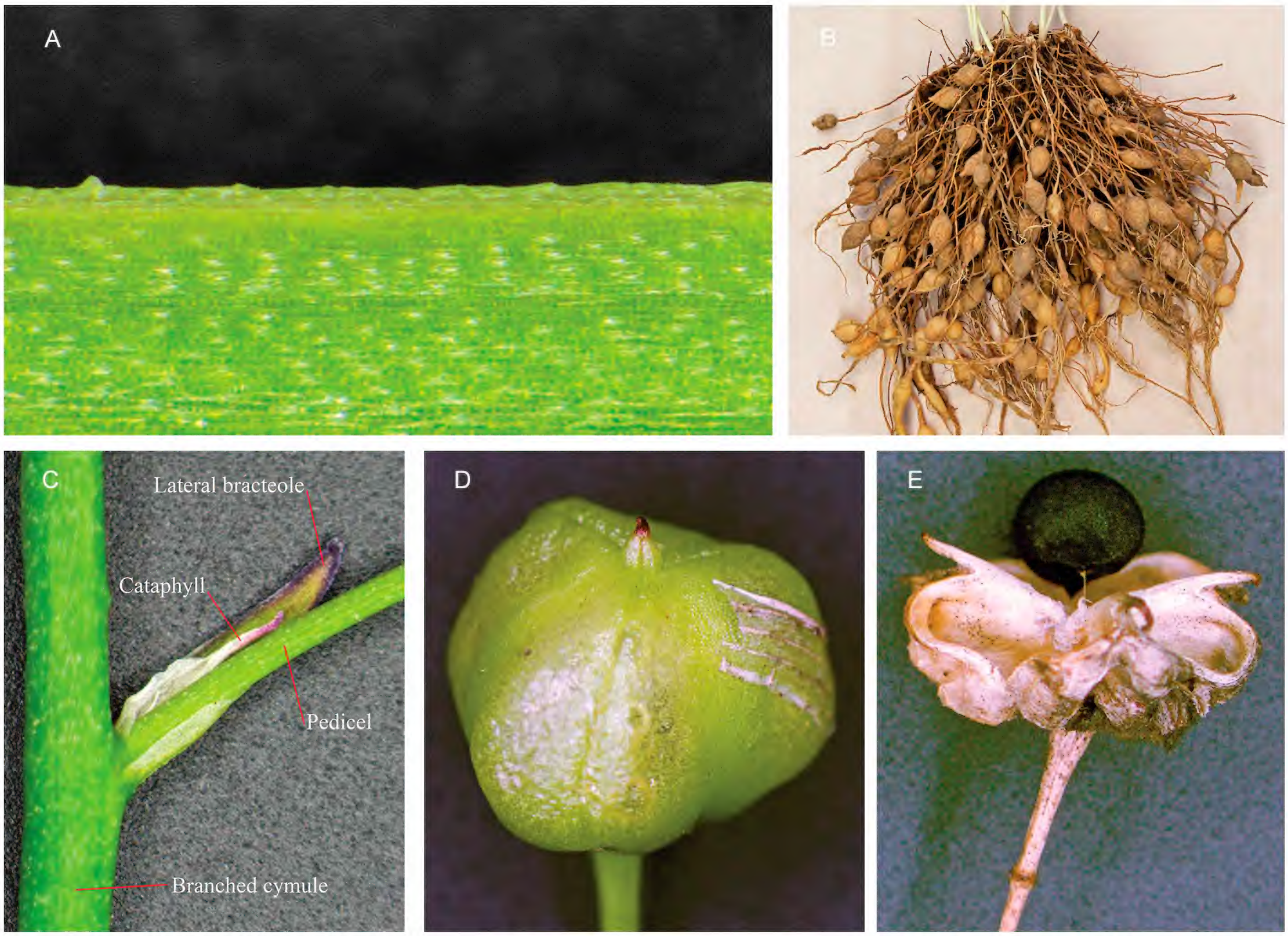


Fig. 3. *Arthropodium boreale* (Hervey Range, Qld, type location population). A. Leaf laminar margin with continuous weakly undulate bullate and sparse asperities. B. Multiple shoots on clumping root structure with thinly fleshed cortex (necks) and short turbinate-fusiform tubers. C. Lateral node bracteole and inner cataphyll on a branched cymule. D. Mature capsule. E. Opened capsule showing prominent beaks (remnant style base).

Selected specimens examined: Queensland. Cook District: Black Rock (Lynd), Apr. 1988, *Horsup 70* (BRI). North Kennedy District: c. 72 km (45 miles) SE of Mt Garnet, Jan. 1968, *Morain 275* (BRI); near Bernhardt's Swamp, c. 5 km WNW of Ravenshoe, Mar. 1979, *Lockyer 184* (BRI); 'Taravale' near Hell Hole Ck, 0.5–1.5 km E of homestead, Mar. 1987, *Jackes 8718* (BRI); Jackes Tableland, Feb 1996, *Cumming 14342* (BRI); Kaban, Jan. 2012, *Wannan 6407, Collins, Freeman* (BRI, NSW).

Distribution and habitat: The occurrence of *A. boreale* is scattered in the tropics of north-eastern Queensland (Fig. 11). Currently known to occur at 380–1000 m altitude. Habitats noted on specimen labels include open woodland on rocky ground, ephemeral wet areas of rhyolite parent material, and an ephemeral soak of grey sandy soils over sandstone. The Hervey Range site is an open *Melaleuca* woodland, with an herbaceous understorey, seasonally inundated on brown, gritty, structured shallow loam over sandstone, and badly weed infested. Associated native species at Hervey Range include *Melaleuca viridiflora* var. *viridiflora*, *Chlorophytum laxum, Lobelia leucotos, Fimbristylis dichotoma, Eleocharis minuta, Aeschynomene indica, Goodenia hirsuta* and *Pimelea sericostachya*, and the site has been invaded by *Lantana camara*.

Conservation status: Data Deficient (IUCN 2019) is suggested for *Arthropodium boreale* until field evaluations of the known (or new) sites occur. The *A. boreale* population close to Townsville occurs in a small seasonal soak, under *Melaleuca viridiflora* var. *viridiflora* and with *Eleocharis minuta*. The problematic weed species *Andropogon gayanus* (Gamba grass) and *Lantana camara* (Lantana) are affecting the site. The long-term security of the population is not guaranteed. To date other occurrences

have not been observed in the field, and an assessment needs to occur to properly ascertain the species conservation status.

Phenology: The shoots of *A. boreale* emerge with the first rains of the northern Australia monsoonal season. Flowering mostly occurs from December to April, before plants dry off at the end of the wet and become dormant. Flowers are open for c. 10.5 hours, with up to 5 individual flowers (1 per node), opening along a branched cymule on a given day. Fruiting is recorded from January to March.

Etymology: The epithet *boreale* is from the Latin *borealis*, meaning north or northern, as this species has the northern most occurrence of the genus in Australia.

Suggested common name: 'Northern Chocolate Lily.'

Affinities: *Arthropodium boreale* is distinctive in the genus in having involute connective tissue on the margins of the filament's apex below the anthers, giving the attached hairs on the abaxial side a cushion-like appearance (Fig. 2B). It has previously been included with *A. strictum*, which differs in having clearly defined caudae (Fig. 4A). *Arthropodium strictum* further differs from *A. boreale* by the erect pedicels held at 25–45° to the scape; the erect, curved stamen filaments that are white and or purple; and slightly ovate anthers and the leaf margins which have raised, separate bullae.

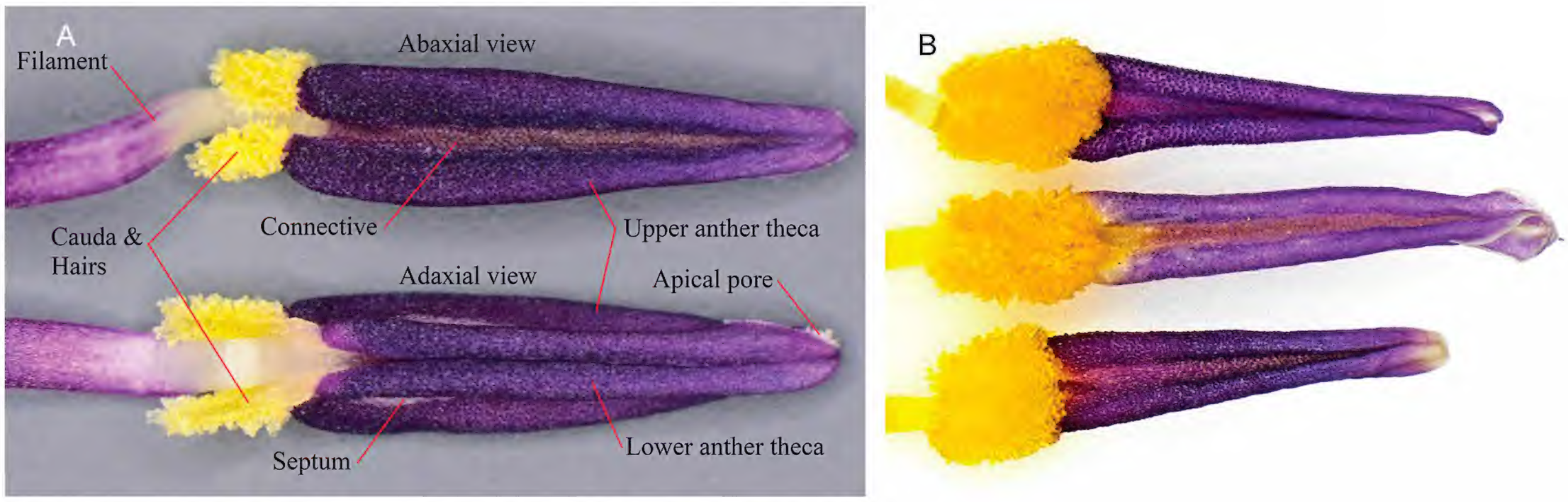


Fig. 4. Staminal comparisons A. *Arthropodium strictum* R.Br. (Benalla, Vic.). B. Comparison of stamen morphology of the three new species, T–B: *A. morganiae* (Carnarvon Gorge National Park, Qld, type location population), *A. boreale* (Hervey Range, Qld, type location population), *A. sejunctum* (Ormiston Pound, West MacDonnell National Park, NT, *Albrecht 13469*, NT).

Notes: Plants in the field were observed being 'buzz pollinated' by several species of native bees during field observations in January and February. However, seed set was poor over a 7–week period. Plants in cultivation have been observed to produce an aerial plantlet at the 1st inflorescence branch node, and also at the 1st flower node along a branched cymule, a trait not observed in the field. The pillow–like covering of the hairs are slightly more elongated along the connective than they are in either *A. morganiae* or *A. sejunctum*. Seed germinates readily in cultivation. White anthers occur naturally but are rare. No floral scent has been noted.

Arthropodium glareosorum P.F.Horsfall & Jian Wang ter, *sp. nov.*

Arthropodium sp. 2, VicFlora https://vicflora.rbg.vic.gov.au (accessed 9 April 2024).

Arthropodium sp. south-east Highlands (N.G.Walsh 811) PlantNET New South Wales Flora online https://plantnet.rbgsyd.nsw.gov.au (accessed 9 April 2024).

Arthropodium sp. Tasmania (N.Brittan s.n.) (Stringer and Conran 1991) misapplied (no specimen found).

Arthropodium sp. B (Conran *et al.* 1996), *p.p.* (note: description combines two species).

Arthropodium sp. 2 (Conran & Walsh 1994).

Type: Queensland. Darling Downs District: Mount Colliery area NE of Killarney, adjacent to Main Range National Park, 18 March 2015, *P.I. Forster PIF42121, G. Leiper & S. Savage* (holo: BRI [AQ838197]).

Deciduous perennial herb, foliage erect, spreading or arching, shoots single. *Roots* 2–20 cm long; *corm* growth is lateral and sequential; neck cortex fleshy; *tubers* fusiform, 1–5 cm long, 3–12 mm wide and tapering into a root from the tuber base for up to 15 cm and true roots occurring along it. *Leaves* ensiform, 2–6 per shoot, 12–35 cm long, 1.5–13(–17) mm wide; *sheath* slightly carinate, white to purple, fleshy; *lamina* flat, adaxial surface green with slightly raised nerves, abaxial surface, midrib smooth, lightly glaucous, lamina margins have rounded and or flat-topped, interrupted bullae (Fig. 5E); *tunic*, none observed. *Inflorescence* 1 per shoot, 15–50(–100) cm long; scape 0.8–1.8 mm diameter, elliptic in cross section, erect, branching 0–3(–6), with 2 or 3 leafy *bracts* below the 1st branch; branches angular, trigonal to ± elliptic in cross section, with nodes spaced along the branch length that are subtended by adpressed, smooth-edged, non-membranous, obtuse, awl-shaped to clawed *bracteoles* reducing toward the apex, 3-nerved; *cymules* condensed at the branch nodes with scarious cataphylls subtending each pedicel; *pedicels* 1–7 per node, 2–12 mm long, ± sharply declined at the bracteole, then pendent. *Flowers* 7–11 mm diameter; *receptacle* 3.1–5.5 mm long, straight, ± slightly curved, sometimes bent slightly up at the occlusion zone of the receptacle base; tepals reflexed; *outer tepals* elliptic to ovate, 3.2–5 mm long, 1–2.2 mm wide, rib 3–veined, faintly pale yellow, white, pale purple or greyish, margins entire; *inner tepals* elliptic, 3–5 mm long, 1.2–3.4 mm wide, sometimes narrower than the outer tepals, rib vaguely

3–nerved, narrow, pale yellow, white, or pale purple suffused onto the flanges, flanges white opaque, margins erose, ± dentate (Fig. 5C). *Stamen*: *filaments* erect, ± slightly curved at the ovary, 1–4 mm long, white, opaque; caudae 0.3–0.6 mm long, extending 2/3–3/4 along the filament below the anthers, adpressed; hairs not very dense to sparse, spread along the filament margin below the anther, untidy, reducing in length down the filament for about 2/3–3/4 of the way to the caudae, white, very rarely with a few minute purple hairs at the base of the anther, apices clavate; *anthers* rectangular, apex obtuse, 0.9–1.5 mm long, fully dehiscent along the septum, cream, connective between the anthers light green. *Pistil: ovary* obpyriforme (quince shaped), 1–1.3 mm high, 0.5–1.1 mm wide, pale green, ivory or fawn; *ovules* 4–6(–8) per locule; *style* 1.3–3.3 mm long, white, opaque, equal to or exceeding the stamens; *stigma papillae*, erect ± spread, 0.03–0.07 mm long, tufted, ± within the width of the style (untidy), apices glandular, white, opaque. *Capsule* globular, lobed, 3–3.9 mm high, 3.2–4.2 mm wide, carpels beaked and exceeding the capsule apex, dehiscence loculicidal from the distal end for about half of the height (as the lower half dries and shrinks it pulls the upper half open, freeing the seed, a bit like opening an umbrella) (Fig. 6B). *Seed* 1.5–1.9 mm long, pustulate, shiny, black. Figures 5, 6.

Selected specimens examined: Queensland. Wide Bay District: Oakview SF, 13 km SE of Kilkivan, Nov. 1990, *Pedley 5582* (BRI); Goods Road, Conondale Ranges, Feb. 1991, *Bean 2867*, *Drake* (BRI). Moreton District: Property of St Peters Lutheran College, 5 km NE of Crows Nest on Black Creek, Jan. 1973, *Sharpe 216 & Durrington* (BRI); Nerang River, 1 km N of Springbrook-Numinbah turnoff, Nov. 1983, *Conran s.n.* (BRI).

New South Wales. North Western Slopes: Slope of Ridge N of Chaffey Dam, Nov. 1993, *Hosking* 874 (NSW). Northern Tablelands: 100 m S of Yarrowitch Falls, Oxley Wild Rivers National Park, Nov. 2015, *Duretto 4123 & Collins* (NSW). North Coast: Rafferty's Creek, c. 5 km direct NNE of East Kunderang Homestead, Oxley Wild Rivers National Park, Nov. 2015, *Duretto 4169 & Wright* (NSW). Central Western Slopes: Pykes Gap, Sandy Hollow to Denham Road, Jan. 1982, *Medd 160234* (NSW). Central Tablelands: Gringa Creek near Kowmung River, Mar. 1951, *Johnson s.n.* (NSW). Central Coast: Middle Harbour, Feb. 1887, *Fletcher s.n.* (NSW).

Fig. 5. *Arthropodium glareosorum*. A. Flower with anther thecae still to open (Ballogie, Qld). B. Hairs along the filament edges of the stamen with tepals removed (Broken Back Range, NSW). C. L–R: Outer tepal and inner tepal (Broken Back Range, NSW). D. Stigmatic papillae (Broken Back Range, NSW). E. Leaf lamina margin with flat and rounded bullate (Queen Mary Falls, Qld).

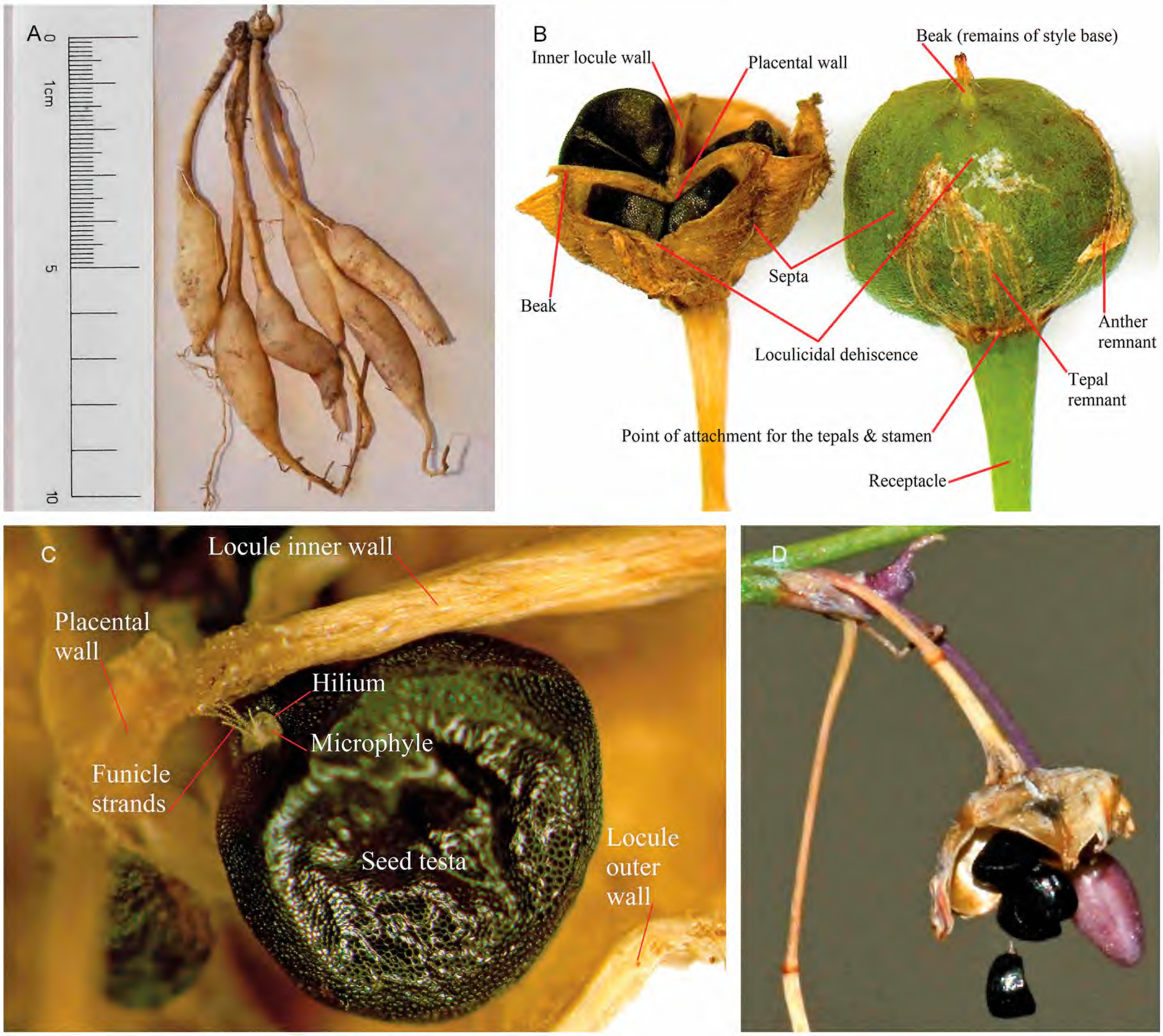


Fig. 6. *Arthropodium glareosorum*. A. Root structure (Broken Back Range, NSW). B. Capsules showing remnant style (beak) at the apex of the carpels and the capsule opening half-way. C. Internal structures of the capsule and seed. D. seed hanging by the funicle strands (Ballogie, Qld).

Distribution & habitat: Widespread in NSW from about the greater Sydney region, west and north to southeast Queensland (Fig. 11). It can be found on gravelly soils derived from rhyolite in generally shallow profiles and also on sandstone derived soils. It occurs in mixed open dry Eucalypt woodland on slopes or ridge tops at altitudes ranging from 30–1000 m.

Conservation status: Least Concern (IUCN 2019) is suggested. *Arthropodium glareosorum* is a common and widespread throughout its range.

Phenology: Flowering has been recorded from November–March with one record in July. Flowers are open for *c*. 9 hours. Inflorescences axes may persist (Fig. 6D) after the leaves have withered and flowering finished. Fruiting is recorded for all months.

Etymology: The epithet *glareosorum* is from the Latin *glareosum*, in reference to the species frequent habitat on gravelly soils.

Suggested Common Name: 'Yellow-anthered Rock Lily'.

Affinities: *Arthropodium glareosorum* has sparse to moderately dense, white, clavate hairs on the filaments and straight, cream-coloured anthers. The style is 1.3–3.3 mm long, with stigmatic papillae 0.03–0.07 mm long, with glandular apices. *Arthropodium glareosorum* has previously been confused with *A. minus* and *A. milleflorum*, but also with *A. strictum* to which there are few similarities. It is distinguished from *A. milleflorum*, which has flowers that are open for *c*. 10 hours, from *c*. 7 am–5 pm, a species with dark purple, recurved anthers (Redouté 1805); hairs along the filament margins that are denser with fine narrow-clavate apices; and a style 3–6 mm long, with clavate stigmatic papillae 0.08–0.28 mm long. It differs from *A. minus*, which has flowers that are open for about 4 hours, from *c*. 8 am–12 pm, a species with root tubers that are sessile; the presence of crowded purple clavate hairs along the filament margins (caudae hairs can be purple or white in *A. minus*); dark purple, recurved anthers; and a style 1–2 mm long, with globular stigmatic papillae.

Notes: There are occurrences from the Main Range National Park in Queensland of *A. glareosorum* [AQ625159] on rocky ridge tops

at an altitude of about 1000 m, where plants have more leaves per shoot (8–10) and are broader (*c*. 17 mm wide) than typical. Additionally, the stem and inflorescence are shorter and thicker, and the branched cymules are more numerous and elongated.

Seed is sometimes retained in the open capsules long after dehiscence, which may account for seed occurring in all months on herbarium sheets. They can often be seen to hang from the open capsule by the funicle threads (Fig. 6C, D). In examining specimens held at MEL, there is no definitive specimen that would equate to *A. glareosorum*, which Conran & Walsh (1994) considered to be *Arthropodium* sp. 2, or to *Arthropodium* sp. B (PlantNET 2024). There is, however, a distinct species in the Eastern Highlands of Victoria, which also occurs in New South Wales. Seed of *A. glareosorum* readily germinates in cultivation. No floral scent has been noted.

Arthropodium morganiae P.F.Horsfall & Jian Wang ter, *sp. nov.*

Type: Queensland. Leichhardt District: Mickey Creek walk car park area, Carnarvon Gorge National Park, 15 November 2021, *P.F. Horsfall PFH4797* (holo: BRI [AQ1045613]; iso: MEL, NSW).

Deciduous perennial herb, foliage erect, spreading, shoots single. *Roots* 2–12 cm long, cortex initially thick, with contractile ribbing and tapering to the tuber, withering at maturity to thinly cover the fibrous stele; *tubers* fusiform, 18–20 mm long, 7–10 mm wide. *Leaves* narrowly ensiform, canaliculate, 3–11 per shoot, 15–31(–66) cm long, 3–8 mm wide; *sheath* canaliculate, clasping, margins smooth, white; *lamina* shallowly canaliculate to flat, dull-green, adaxial surface smooth, abaxial surface ± faintly glaucous (easily brushed off), with slightly raised nerves, midrib smooth, laminar margins have interrupted, flat topped bullae with occasional acute asperities (Fig. 8A); *tunic* occasionally with a few short main vein remnants. *Inflorescence* 1 or 2 per shoot, 26–70(–100) cm long, scape to 2 mm diameter, round in cross section; *bracts* 1–2 before the 1st branch, long, narrow,

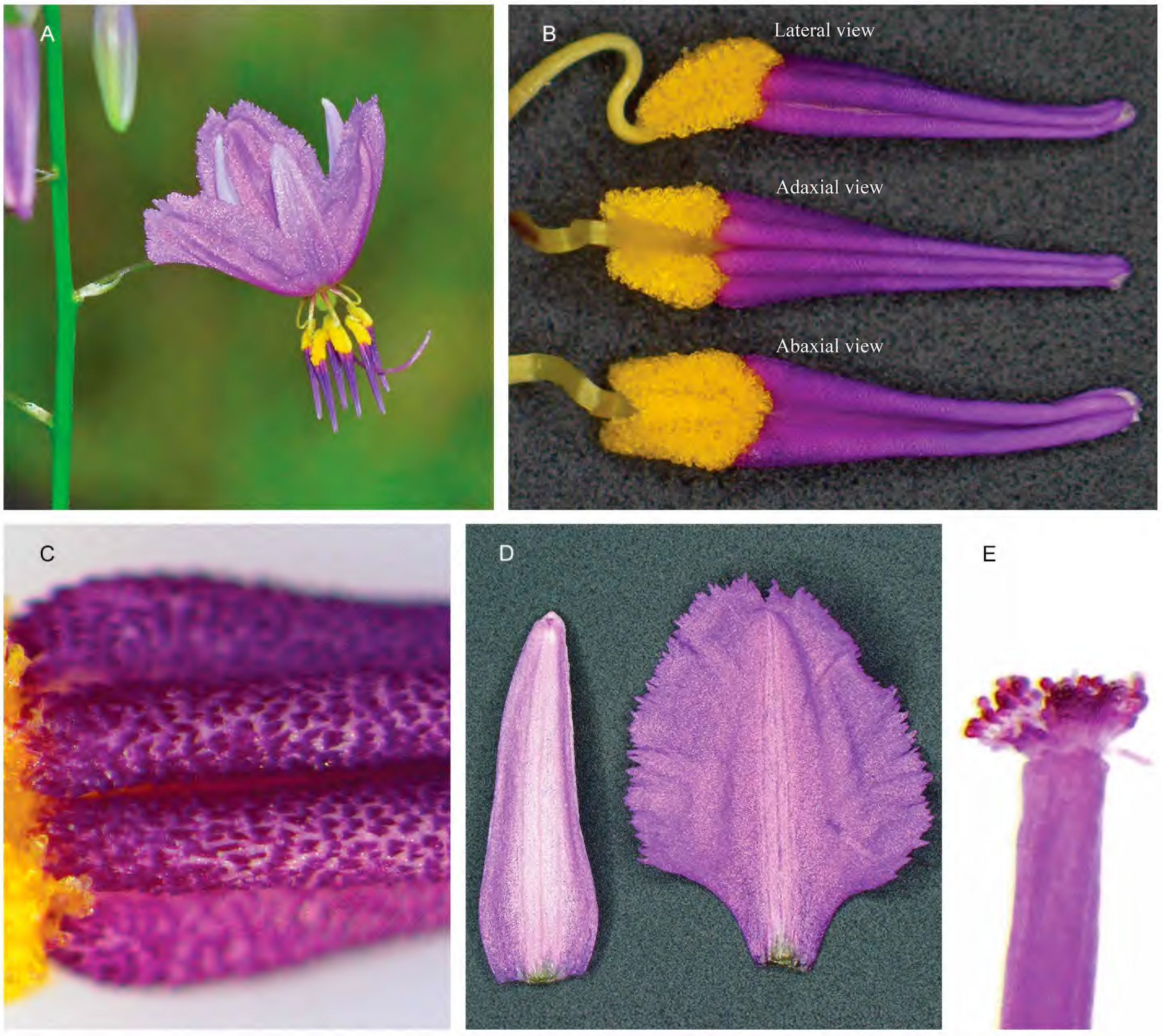


Fig. 7. *Arthropodium morganiae* (Carnarvon Gorge National Park, Qld, type location population). A. Flower and bracteole at the base of the pedicel. B. Different views of the stamen, T–B: Lateral view showing the small apical pore of the anther and sigmoid filament. Adaxial view showing the open connective. Abaxial view showing the hairs. C. Anther patterning detail lower theca. D. L–R: Inner tepal and outer tepal. E. Stigmatic papillae.

encompassing c. half the stem, reducing in size toward the apex, edges smooth; *branched cymules* 1–5, terete in cross section, becoming semi-terete, usually held erect and spreading, but held relatively close to each other, green to lightly glaucous; secondary branchlets sometimes present; *pedicels* erect, ± slightly bowed, 1, rarely 3 per node, 42–22 mm long, widely divergent at 45–100°, becoming erect after pollination or flower aborting; subtended by an adpressed unguiculate *bracteole* with membranous edges clasping the pedicel and nearly encircling it at the base, then sharply reducing from about 1/3 of its length from the base, apex with minute forward-facing asperities on the edges and abaxially. *Flowers* 18–28 mm diameter, nodding; *receptacle* 2–4 mm long, erect or slightly curved at anthesis, from the articulation of the receptacle and pedicel, then becoming erect with pollination and fruit maturity, sometimes darkening to a blackish colour; tepals dimorphic, reflexed, concolorous; *outer tepals* lanceolate, 7–12 mm long, 2–4.6 mm wide, ribs 3–nerved occasionally 5, abaxially pale whitish pink, adaxially pale pinkish to purplish, base green, edging onto the tepals on both sides; *inner tepals* elliptic, 8–12.5 mm long, 3.5–10 mm wide, notched at the apex, rib wide, 3-nerved, nerves closely spaced, flanges extended, unevenly undulate, finely and unevenly dentate on the edges, pinkish-purple to purple, base green edging onto the tepals on both sides, rarely white at the base. *Stamen*: *filaments* sigmoid nearer the apex, tapering, 3.2–3.5 mm long, base purple, becoming pale greenish–yellow toward the hairs,

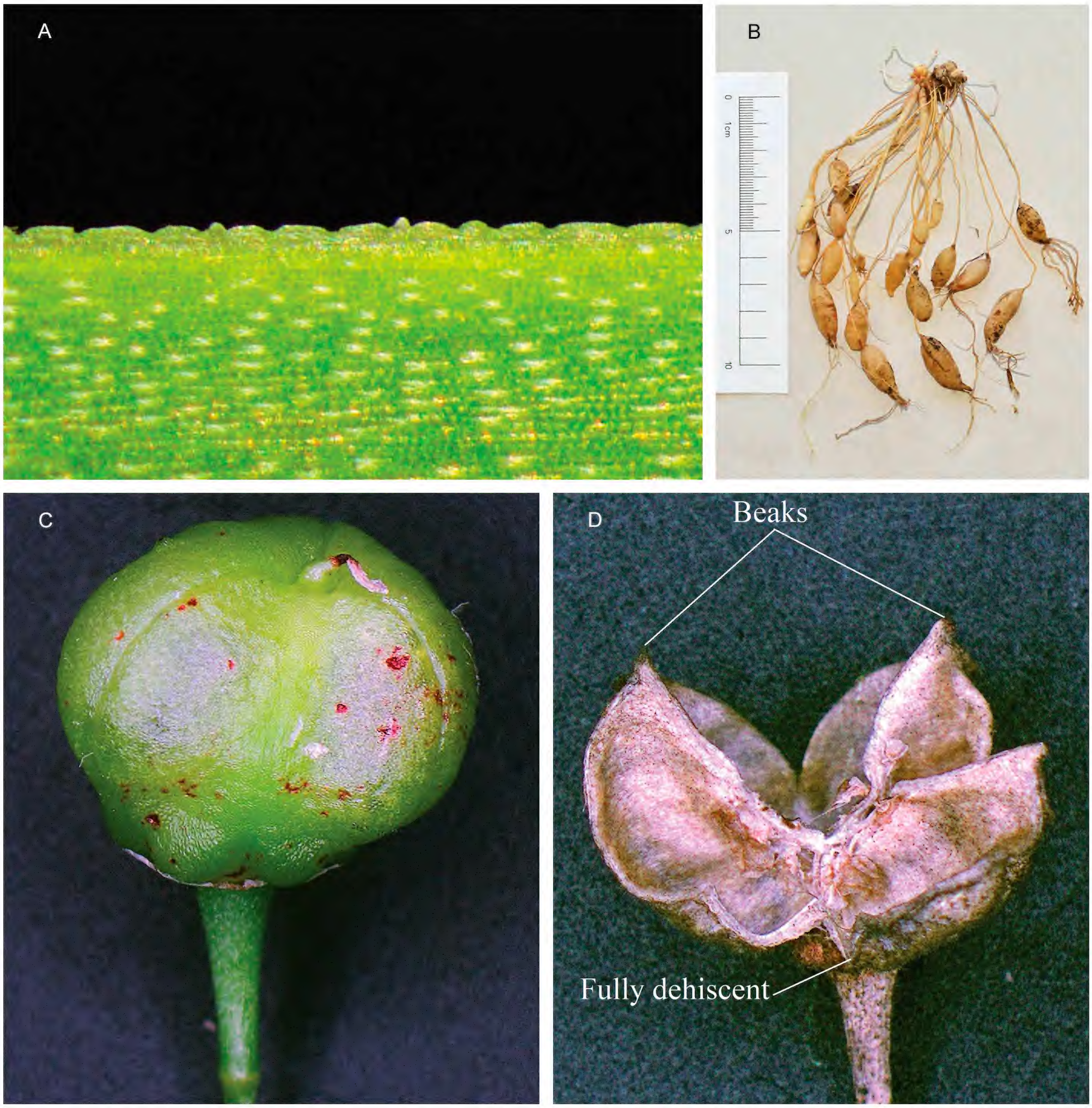


Fig. 8. *Arthropodium morganiae* (Carnarvon Gorge National Park, Qld, type location population). A. Lamina margin with flat topped bullate. B. Root structure with single sequential corm growth, cortex (neck) initial thickened growth, tapering and reducing to the fibrous stele. C. Mature capsule. D. Opened capsule.

rarely white; *caudae*, rudimentary; *hairs* dense, irregular lengths, abutting the base of the anthers and shortly down the filament, on connective tissue that is involute, leaving the adaxial side of the filament relatively bare and the margins and abaxial side covered (angular, cushion-like appearance), apices glandular, ± angustata, clavate, bright yellow; *anthers* 3.2–4.7 mm long, 0.7–0.9 mm wide, narrowly triangular, ± twisting to *c*. 90°, apex acute, poricidal opening small, anthers covered with distinct forward-facing, triangular, dark purple pigmentation, scale-like (Fig. 7C), becoming finer and paler toward the apex. *Pistil*: *ovary* elliptic, 1.2–1.3 mm high, 1.4 mm wide, pale green to mid-green; ovules 6–9 per locule; *style* 5.8–8 mm long, pale yellow or white from the base for *c*. 1.5 mm then becoming purple toward the stigma; *stigma papillae* 0.12–0.16 mm long, tufted, exceeding the style width with glandular and clavate apices, purple, white, or mixed. *Capsule* globular, slightly lobed and locules slightly countersunk at the apex, 4.5–6.4 mm high, 4.3–6.4 mm wide, loculicidal dehiscence, locule apices beaked, locules fully dehiscent (Fig. 8D). *Seed* 1.6–2.4 mm long, testa pustulate black, shiny. Figures 4B (top), 7, 8.

Selected specimens examined: Queensland. Leichhardt District: Palmgrove NP, NW of Taroom, Bigge Range, Nov. 1998, *Forster PIF23713 & Booth* (BRI); Kentucky Holding, at Dawson River, c. 48 km NE of Injune, S Central Qld, Oct. 2011, *Aisthorpe CPE1972 & Wamer* (BRI). Burnett District: Narayen, 1 Mar. 1973, *ignotus N1338* (BRI); Three Moon Ck, S of Mulgildie, Nov. 1995, *Bean 9171 & Turpin* (BRI). Wide Bay District: Chowey Ck, 4 km NNE of Didcot, Jul. 1990, *Forster PIF6965* (BRI). Maranoa District: 'Six Mile', north flat paddock, NNW of Roma, Nov. 2005, *Eddie CPE959* (BRI); 'Oakwells', W of Injune, Oct. 2007, *Eddie BC020 & Cosh* (BRI). Darling Downs District: Chinchilla, Nov. 1933, *Beasley 202* (BRI); Sundown NP, along 4WD track in northern section of the park, Nov. 1998, *Hazelgrove 74* (BRI). Moreton District: Gatton, 1 Nov. 1903, *Bailey s.n.* (BRI).

New South Wales. Northern Tablelands: Jennings, Dec. 1903, *Maiden s.n. & Boorman* (NSW). North West Slopes: About 22 km (direct) NNW of Ashford; 150 m SE of Macintyre Falls carpark and picnic area, Macintyre Falls Fauna and Flora Reserve. Oct. 1990, *Makinson 684, Coveny & Quirico* (NSW).

Distribution & habitat: *Arthropodium morganiae* occurs in southeast Queensland from Carnarvon Gorge National Park, south to northeast New South Wales (Fig. 11). In Queensland it is found as an understorey plant in open *Angophora*, *Corymbia* and *Eucalyptus* woodlands, grassland, and heathland. Occurring from 120–1180 m altitude and on a range of soils including clays, clay and sandy loams, sandy soils, and alluvium and can sometimes be locally common.

Conservation status: Data Deficient is suggested (IUCN 2019). Populations of *A. morganiae* appear to be somewhat disjunct throughout the SE Queensland and NE New South Wales range and poorly understood.

Phenology: Flowering is recorded from October through to March with one record occurring in July. Flowers are open for *c*. 9.5 hours. Fruit is recorded for October, February, and March.

Etymology: This species is named in honour of Caroline Morgan formerly of 'Vegetation Matters' in SE Queensland for her commendable skills of hands-on ecological field-work and botanical assessment work.

Suggested Common Name: 'Caroline's Chocolate Lily'.

Affinities: *Arthropodium morganiae* and *A. boreale* are distinctive in the genus in having involute connective tissue on the margins of the filament's apex below the anthers, giving the attached hairs on the abaxial side a cushion-like appearance. *Arthropodium morganiae* can be distinguished from *A. boreale* by not having roots that are clumping or with fleshy necks. Leaves with low almost separated bullate on the margins. Pedicel bases with subtending bracteoles that are clawed and clasp at the base. The outer flange of the inner tepals is finely serrate. The overall form of the hairs on the abaxial side of the filaments are angular with a small cleft at the base (almost a pentagon in shape). Anthers with an acute apex. It has previously been included with *A. strictum*, which differs in having clearly defined cauda. *Arthropodium strictum* further differs from *A. morganiae* by the erect pedicels held at 25–45° to the scape, the erect, curved stamen filaments that are white and or purple. Slightly ovate anthers and the leaf margins which have raised separate bullae.

Notes: *Arthropodium morganiae* is a warm-temperate species, occurring below the tropic of Capricorn. It has been confused in NSW with *A. strictum*, but that species does not seem to occur much north of Sydney, at least not in the east. No floral scent has been noted.

Arthropodium sejunctum P.F.Horsfall & Jian Wang ter, *sp. nov.*

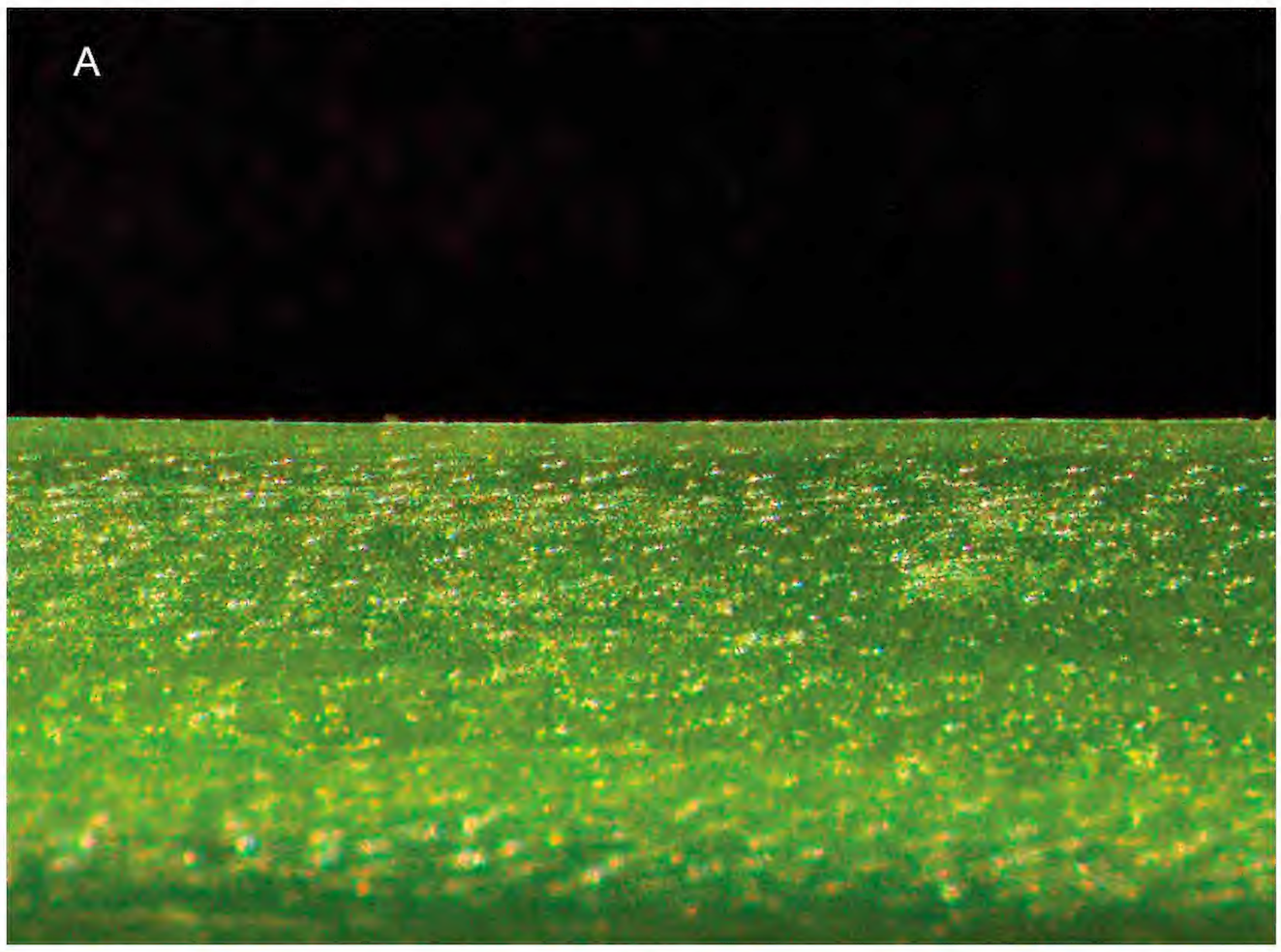
Type: Northern Territory. Southern Region: NE Mt. Sonder, 8 July 1998, *P.F. Horsfall PFH 534* (holo: NT [A0096391]).

Deciduous perennial herb, foliage initially erect, spreading, ± reclining, shoots single. *Roots* 6.5–15 cm long; *corm* growth is lateral and sequential; *neck* cortex fleshy, increasing in diameter toward the tuber, with contractile ribbing along the length; *tubers* fusiform to narrowly ovoid, 30–50 mm long, 7–15 mm wide. *Leaves* linear to narrowly ensiform, canaliculate, 5–16 per shoot, 10–50 cm long, 1–6 mm wide; *sheath* canaliculate, clasping at the base of the shoot, margins smooth, white; *lamina* 15–33 cm long, 4–6 mm wide, adaxial surface smooth, glabrous, abaxial surface matt with ridged venation, margins entire (acute in cross section), with occasional minute asperities (Fig. 10A); *tunic* short, sparse, consisting of remnant leaf sheath nerves surrounding the corm. *Inflorescence* 1 or 2 per shoot, 31–113 cm long, usually much shorter; scape 1.1–4.5 mm diameter, elliptic to circular in cross section, glabrous, smooth, subtended by 1 or 2 *bracts* before the 1st branch and reducing in size toward the apex; branched cymules 0–6, occasionally 2 or 3 at a node on the main scape, secondary branchlets sometimes present; *pedicels* ± weakly undulate, 1 per node, spread to between 45–80° at anthesis, 10–45 mm long and reducing in length toward the branch apex, with a collar at the pedicel base; subtended by a solitary adpressed bracteole; bracteole narrow elliptic to oblanceolate, deeply concave midpoint ± loosely clasping the pedicel, membranous margins becoming scarious in fruit. *Flowers* 16–26 mm diameter, erect to semi-nodding, 1–3 open per branched cymule (1 per node) at any one time; *receptacle* 0.9–3.5 mm long, straight to slightly recurved at anthesis, ± declined in fruit; *tepals* dimorphic, recurved; o*uter tepals* narrowly elliptic, 7.5–13 mm long, 2.5–3.8 mm wide, abaxial surface pale bluish-purple, adaxial surface purple, *rib* 3–nerved;

inner tepals broadly elliptic, 8–12 mm long, 5–10.5 mm wide, pink or purple, *rib* 3–nerved; *flange* undulate, margins irregularly dentate, erose, exceeding the rib apex. *Stamen: filaments* tapering and sigmoid toward the apex, 2.7–4.5 mm long, golden yellow; *caudae* 0.3–0.4 mm long; *hairs* dense, relatively uniform in length and abutting the anther bases and slightly extending down the filament on connective tissue that is involute, leaving the adaxial side of the filament bare and the margins and abaxial side covered (a compact cushion-like appearance), apices glandular, golden yellow; *anthers* narrowly triangular, 2.5–5 mm long, pink or purple with irregular pustule-like scaly covering (Fig. 9C) becoming smaller and paler toward a blunt, obtuse apex. *Pistil: ovary* globular, weakly lobed, apex well recessed, beaks not visible, 0.9–1.7 mm high, 0.9–2 mm wide, light green; *ovules* 6–8 per locule; *style* 5.2–8 mm long, cream to yellow for *c.* 1 mm at the base, purple above; *stigma papillae* 0.14–0.18 mm long, uniformly clavate, tufted, untidily arranged, dark purple, or some white. *Capsule* globular, lobed, 2.5–4.7 mm high, 1.2–5 mm wide, partially dehiscent for about 1/3 of length. Capsule base shrinks upon drying and locules become fully reflexed, capsule thin and papery, brittle; locules recessed at the apex with small apical beaks (remnant style base) well-recessed (Fig. 10D). *Seed* 1.5–1.8 mm long, pustulate, shiny, black. Figures 4B (bottom), 9, 10.

Selected specimens examined: Northern Territory. Central Australia South Region: Ormiston Pound; c. 9 km due West of Mt Giles, Jun. 2010, *Albrecht 13469* (NT); Petermann Ranges Reserve, Pottoyu Hills 16 km south of Lasseters Cave, Sept. 1978, *Henshall 2252* (DNA); NE of Mt Sonder, Jul. 1998, *Horsfall 534* (NT); Fringe Lily Gorge, East Chewing Range, Oct. 1984, *Latz 9963* (DNA); Learmouth Park, Livingstone Pass, National Park, Mar. 1967, *Butler s.n.* (PERTH).

Fig. 9. *Arthropodium sejunctum* (Ormiston Pound, West MacDonnell National Park, NT). A. Flower and concave bracteole at the base of the pedicel (Photo: David Albrecht). B. Different views of the stamen, T–B: Lateral view showing the rounded (blunt) and pale anther apex and sigmoid filament. Adaxial view showing the open connective. Abaxial view showing the hairs. C. Anther patterning on upper theca. D. L–R: Outer tepal and inner tepal. E. Stigmatic papillae. Voucher: *Albrecht 13469* (NT).



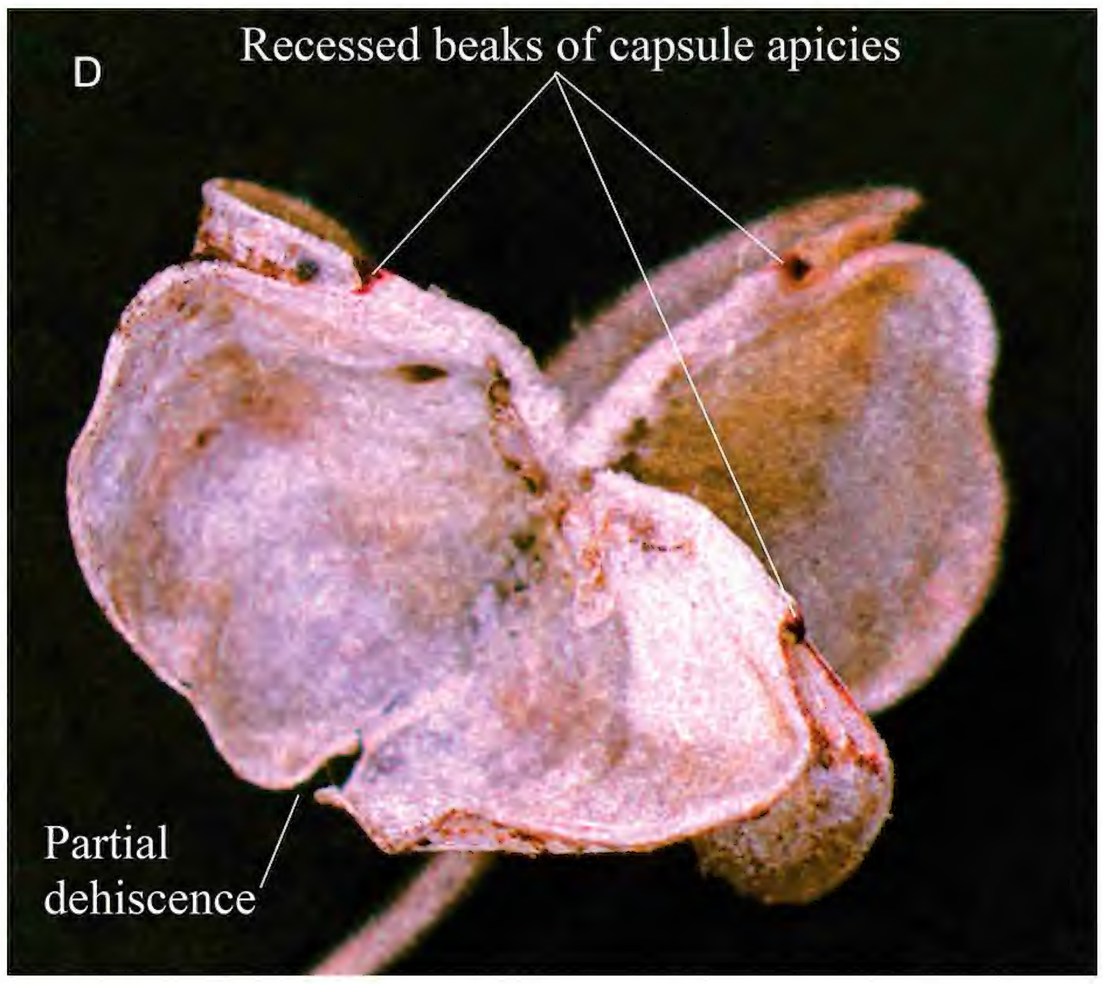


Fig. 10. *Arthropodium sejunctum* (Ormiston Pound, West MacDonnell National Park, NT). A. Lamina margin entire (acute in cross section) with occasional minute asperities. B. Root structure (2 plants shown). C. Recessed apex of mature capsule. D. Opened capsule showing the partial loculicidal dehiscence and deeply recessed small beaks. Voucher: *Albrecht 13469* (NT).

South Australia. North West Region: Mann Ranges, Edwin Valley Springs, Apr. 2001, *Bates 58257* (AD); Mintabie area, Apr. 1997, *Bates 47358* (AD); S slopes of Mt Lindsay proper, c. 1 km E of Watarunga Rockhole, Aug. 1978, *Donner 6421A* (AD); Mountain 5 km S of Oortoorminna Springs and E side of Jacky Pass, Musgrave Ranges, Jul. 2009, *Duguid 1022 & Latz* (AD); Mt Etitinna, 19 km SW of Mimili, Sept. 2009, *Latz 24936* (AD). Flinders Ranges: Arkaroola Sanctuary, S of Headquarters, Oct. 1971, *Kuchel 2991* (AD).

Distribution and habitat: *Arthropodium sejunctum* has a disjunct occurrence in southern Northern Territory and north-western South Australia (Fig. 11). In the Northern Territory it occurs in the west MacDonnell Ranges and in the Pottoyu Hills (Petermann Ranges area). In South Australia it occurs in the Musgrave Ranges, the Mann Ranges, Mount Lindsay, Illbillee Range, and the Everard Ranges. There is also a single occurrence (*Kuchel 2991*), from the Flinders Ranges. It occurs on depauperate soils. Habitat is varied. In the Northern Territory it can be found along seasonal drainage lines, on low hills, and soaks. In South Australia it has been recorded from hilly and low-mountainous locations.

Conservation status: Least Concern is suggested (IUCN 2019). This species is secure in the central Australia Southern Region of the Northern Territory and the North-west Region of South Australia as locations are remote.

Phenology: Flowering is recorded April, June–July, September–October. Flowers are open for c. 10.5 hours. Fruit is recorded in June–July, September–October.

Etymology: The Latin epithet *sejunctum* means separately, in reference to the separateness and remoteness of its occurrence relative to other *Arthropodium* species (*A. vanleeuwenii* is another exception).

Suggested Common Name: 'Desert Chocolate Lily'.

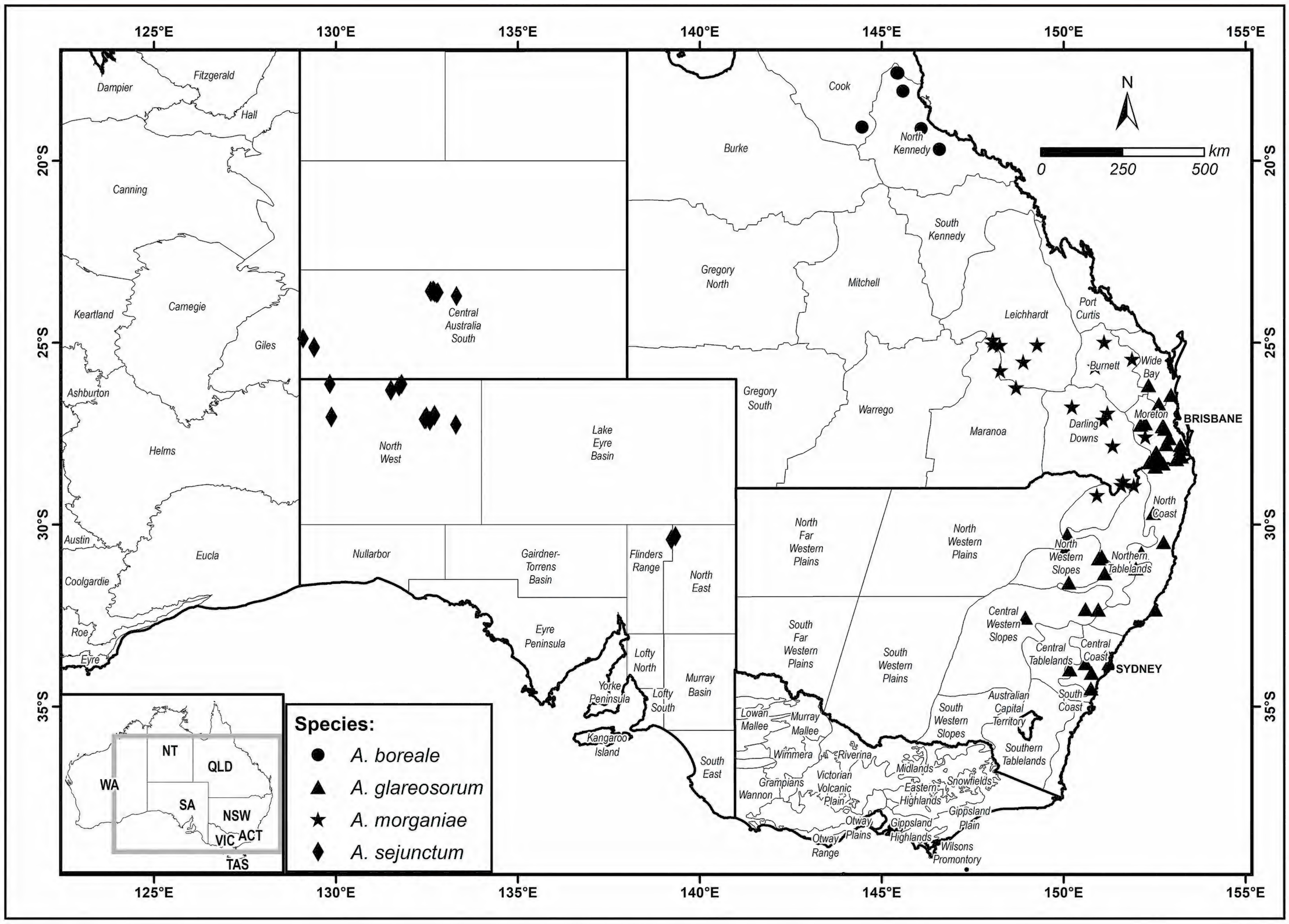


Fig. 11. Distribution map of the four new *Arthropodium* species. ● *A. boreale*; ▲ *A. glareosorum*; ★ *A. morganiae*; ◆ *A. sejunctum*.

Affinities: *Arthropodium sejunctum*, *A. boreale* and *A. morganiae* are distinctive in the genus in having involute connective tissue on the margins of the filament's apex below the anthers, giving the hairs on the abaxial side a cushion-like appearance. *Arthropodium sejunctum* can be distinguished from *A. boreale* and *A. morganiae* by the thicker root necks and longer tubers that taper gradually to the neck (10B); filaments and hairs that are golden yellow (rather than paler and different shades of yellow); hair clusters that are compact; the anther apex more obtuse and paler in colour, but not flared or acute; the outer flange of the inner tepals is coarsely serrate; and the leaf margins are mostly smooth, with occasional asperities. It has previously been included with *A. strictum*, which differs in having clearly defined cauda. *Arthropodium strictum* further differs from *A. sejunctum* by the shorter, fusiform to turbinate tubers with fibrous necks; the erect pedicels held at 25–45° to the scape; the erect and curved stamen filaments that are white or purple; slightly ovate anthers; and the leaf margins which have raised bullae.

Notes: Some specimens from the Everard Range appear intermediate between *A. sejunctum* and *A. strictum*. Some pedicels are more erect and not widely spreading as is the case with *A. strictum*, which are held at *c.* 25–45°, whereas *A. sejunctum* is held at *c.* ± 80°. The specimen *Kraehenbuehl 3938* has an inflorescence nearly 140 cm long. The longest recorded inflorescence for *A. sejunctum* is 113 cm and *A. strictum* is 127 cm, both not far off 140 cm, but these measurements are at the far end of average lengths for both species and this might suggest hybrid vigour. The stamens have filaments that are purple in colour at the base, which can be seen in *A. strictum* but not in *A. sejunctum*, which are a uniform golden yellow. The stamen filament shape is sigmoid as occurs in *A. sejunctum* but not in *A. strictum*, which are erect. The anthers appear to have distinct caudae, unlike *A. sejunctum*. The specimen *Eichler 17512* has stamens with distinct caudae, but the filaments are sigmoid, and pedicel bracteoles as occur on *A. sejunctum*. The specimen *Canty BS104–994* from the Gammon Ranges also appears to be a hybrid with *A. strictum*. Its stamens resemble those of *A. sejunctum,* but the base of the inflorescence has remnant leaf nerves (tunic) which is common on *A. strictum*.

The South Australian Everard Range material is determined as *A. sejunctum*, but needs further study. If *A. strictum* does occur through the Everard Range, it is the furthest NW and disjunct occurrence known for that species. The closest occurrence of *A. strictum* is the northern end of the Flinders Rangers. The same applies to the occurrence of *A. sejunctum* in the Flinders Ranges and both require further scrutiny to see if both parents occur in those areas. It should be noted that *A. strictum* also naturally hybridises with a number of other *Arthropodium* species. *Arthropodium sejunctum* is likely to be found in the Central East of Western Australia, given its proximity near Docker River, Northern Territory (10 km east of the Western Australia border).

Several small native bee and hoverfly species have been observed visiting flowers in cultivation. The bees buzz-pollinate

the flowers, and the flies while hovering very close have a similar effect. The vibration results in the pollen being ejected from the hollow anthers. Floral scent has been noted for Northern Territory populations by a visitor to the first authors material as being faint and sweet. A collection of the species by R.J. Bates (AD) at one site in South Australia describes the scent as a "sweet vanilla odour, not chocolate" and at other sites not having an odour. Bates also noted the difference of the stamen. In cultivation, *A. sejunctum* flowers almost continuously and plants will form clumps with multiple shoots.

Conclusions

We here provide a key and a table of diagnostic characters (Table 1) to distinguish the four new species from currently names species in central and eastern Australia.

Key to the *Arthropodium* species of central and eastern Australia

1 Anthers with lateral dehiscence 2
1. Anthers with apical dehiscence 4
2 Anthers straight, yellow ..... **A. glareosorum**
2. Anthers recurving, purple 3
3 Roots with fleshy necks and fusiform tubers; tepals white, ± pinkish ..... **A. milleflorum**
3. Roots sessile, tubers narrowly turbinate; tepals purple ..... **A. minus**
4 Anthers purple, with a yellow-haired cushion; caudae indistinct 5
4. Anthers purple, without a yellow-haired cushion; caudae distinct 7
5 Anther apex flared; shoots multiple ..... **A. boreale**
5. Anther apex not flared; single shoot 6
6 Anther apex acute; root neck fibrous ..... **A. morganiae**
6. Anther apex blunt, rounded; root neck fleshy ..... **A. sejunctum**
7 Pedicels multiple, drooping; filaments sigmoid; caudae with purple hairs ..... **A. fimbriatum**
7. Pedicels single, erect; filaments erect; caudae with yellow hairs ..... **A. strictum**

Note: Other keys to *Arthropodium* species can be found in Brittan (1987), Conran & Walsh (1994) and KeyBase (2024).

Table 1. Diagnostic characters for *Arthropodium* species in Central and Eastern Australia.

	A. fimbriatum	*A. strictum*	*A. boreale*	*A. morganiae*	*A. sejunctum*	*A. milleflorum*	*A. minus*	*A. glareosorum*
Root systems	necks fibrous, tubers fusiform	necks fibrous, tubers turbinate to fusiform	necks fibrous, tubers turbinate to fusiform	necks fibrous, tubers fusiform	necks fleshy, tubers fusiform	necks fleshy, tubers fusiform	tubers sessile, fusiform	necks fleshy, tubers fusiform
Inflorescence No.	1–5	1–5	1	1 or 2	1 or 2	1–3	1–4	1
Inflorescence length (cm)	30–90	19–127	33–60	26–70	31–113	14–98	8–47	15–50
Cymule type	condensed	branched	branched	branched with branchlets	branched with branchlets	condensed	scape, branching rare	condensed
Flower width (mm)	15–27	12–30	20-25	18–28	16–26	9–18	8–10	7–11
Flower colour*	purple	purple	purple	purple	purple	white	purple	white
Flowers open / close	5am–1pm	3am–4pm	5am–3.30pm	5am–2.30pm	6.30am–5pm	7am–5pm	8am–12pm	5am–2pm
Staminal hairs	purple on caudae, apex obtuse	yellow on caudae, apex glandular	yellow, cushion-like abaxially at filament apex, apex glandular	yellow, cushion-like abaxially at filament apex, apex glandular	yellow, cushion-like abaxially at filament apex, apex glandular	all white or ½ white & ½ purple or all yellow, apex clavate	all purple or along filament purple & caudae white, apex clavate	white along filament, apex clavate
Anther length (mm)	3.6–5.5	3–4.5	3–3.8	3.2–4.7	2.5–5	1.5–2.5	0.7–1.2	0.9–1.5
Anther shape	triangular	narrowly ovate	triangular	triangular	triangular	rectangular, recurving ± 180°	rectangular, recurved	rectangular, straight
Anther colour	purple	purple	purple	purple	purple	purple	purple	yellow
Anther dehiscence	poricidal	poricidal	poricidal	poricidal	poricidal	lateral	lateral	lateral
Occurrence	Qld, NSW, Vic., SA, WA	NSW, Vic., SA, Tas.	N Qld	SE Qld, NE NSW	NT, SA	Qld, NSW, Vic., SA, Tas.	Qld, NSW, Vic., SA, Tas.	Qld, NSW

Disclosures

The authors declare no conflict of interest.

Declaration of Funding

This research did not receive any specific funding.

Data availability statement

The data that support this study are all available in the manuscript.

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References

Angiosperm Phylogeny Group (APG) II (2003) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. *Botanical Journal of the Linnean Society* 141: 399–436. DOI

Angiosperm Phylogeny Group (APG) III (2009) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants. APG III. *Botanical Journal of the Linnean Society* 161: 105–121. DOI

Angiosperm Phylogeny Group (APG) IV (2016) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnean Society* 181: 1–20. DOI

Brittan NH (1987a) *Arthropodium*. Pp. 341–344 in AS George (ed.) *Flora of Australia* Vol. 45. (Australian Government Publishing Service: Canberra)

Brittan NH (1987b) *Dichopogon*. Pp. 345–348 in AS George (ed.) *Flora of Australia* 45. (Australian Government Publishing Service: Canberra)

Brown R (1810) *In Prodromus Florae Novae Hollandiae et Insulae Van-Diemen Exhibiens Characteres Plantarum*. Vol. 1. (Richard Taylor and Associates: London) DOI

Cheeseman T (1906) *Manual of the New Zealand Flora*. (John Mackay, Government Printer: Wellington). DOI

Conran JG, McCune S, Harden DW (1993) *Dichopogon & Arthropodium*. In Harden GJ (ed.), *Flora of New South Wales*. Vol. 4. pp. 95. (University of New South Wales Press: Kensington)

Conran JG, Walsh NG (1994) Liliaceae. In Walsh NG, Entwisle TJ (eds), *Flora of Victoria Volume 2. Ferns and allied plants, conifers and monocotyledons*. pp. 637–686. (Inkata Press: Melbourne)

CHAH (2024) Australian Plant Census. URL (accessed 6 January 2024)

Dahlgren RMT, Clifford HT, Yeo PF (1985) *The families of the monocotyledons: structure, evolution and taxonomy*. (Springer-Verlag: Berlin)

Dillon SJ, Macfarlane TD (2020) Leeuwen's Lily (*Arthropodium vanleeuwenii*: Asparagaceae), a remarkable new discovery from the Pilbara, Western Australia. *Nuytsia* 31: 265–269. DOI

IUCN Standards and Petitions Committee (2019) *Guidelines for using the IUCN Red List Categories and Criteria. Version 14. Prepared by the Standards and Petitions Committee*. PDF

KeyBase (2024). Flora of Australia: vascular plants: Species of *Arthropodium*. URL (accessed 9 April 2024)

PlantNET (2024) New South Wales Flora online. *Arthropodium*. URL (accessed 8 March 2024).

POWO (2024) Plants of the World Online. The Royal Botanic Gardens, Kew. URL (accessed 6 January 2024).

Redouté P-J (1805) *Les Liliacées* Vol. 1: t. 58. (Chez l'auteur: Paris). DOI

Redouté P-J (1812) *Les Liliacées* Vol. 6: t. 360. (Chez l'auteur: Paris). DOI

Stringer S, Conran JG (1991) Stamen and seed cuticle morphology in some *Arthropodium* and *Dichopogon* species (Anthericaceae). *Australia Journal of Botany* 39: 129–136. DOI

VicFlora (2024) Flora of Victoria. URL (accessed 8 March 2024)

Wang J, Horsfall PF (2024) Lectotypification of the name *Arthropodium candidum* Raoul (Asparagaceae). *Adansonia* 46(6): 41–44. DOI

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Lecanora darelensis, a new species of Lecanoraceae from Darel Valley, Gilgit Baltistan, Pakistan

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Abstract

A new species, *Lecanora darelensis* sp. nov. is described here from Darel Valley, Gilgit Baltistan, Pakistan. A comparative morpho-anatomical, chemical study and ITS-based molecular analyses confirmed the position of new species within the genus *Lecanora*. The new taxon is phylogenetically closely related to *L. argopholis*. The former can be distinguished from latter in having pale yellowish green upper surface (vs yellowish white), larger apothecial disc 0.5–1.5 mm (vs c. 1.2 mm), brown, plane to convex, pruinose to rarely epruinose apothecial disc (vs deep yellowish brown, plane or slightly concave, epruinose), taller epihymenium 25–35 µm (vs c. 20 µm), taller hymenium 110–150 µm (vs 70–75 µm), larger ascospores 14–18 × 5–8 µm (vs c. 12.7 × 7.3 µm), atranorin is detected by TLC (vs atranorin, epanorin, zeorin) and growing on calcareous rocks (vs rock surfaces, detritus, mosses, sloping siliceous and calcareous rocks, boulders, gravel).

Introduction

Lecanora Ach. (Lecanoraceae) is a large group of crustose lichens that is distributed worldwide (LaGreca & Lumbsch 2001; Lücking *et al*. 2017). It is defined by its hyaline, simple oval spores, *Lecanora*-type asci, thalline amphitecial cortex, Lecanorine apothecia and crustose habit (Hafellner 1984; Henssen & Jahns 1974). This lichen genus serves as the type for one of the largest orders of euascomycetes, the Lecanorales, and it has been reported for *Lecanora sensu lato* that includes well over 1,000 species (Zahlbruckner 1926). The region of Gilgit-Baltistan, formerly known as the 'Northern Areas', forms part of northern Pakistan amidst the Karakoram, Greater Himalayas, Pamir, and Hindu Kush mountain ranges. It shares international borders with Afghanistan to the northwest, China to the northeast, and India in the east. Administratively, the region is divided into seven districts – Astore, Diamer, Ghanche, Ghizer, Gilgit, Hunza-Nagar and Skardu with the administrative capital in Gilgit city (Khan *et al*. 2013).

Sampling was undertaken in the Darel Valley, Gilgit Baltistan. Darel Valley is dominated by barren mountains with patches of fertile land with pastures. The samples were collected in a cold, semi–arid climate at an altitude of 2,000 m a.s.l. The climate has typically cold desert characteristics, with severe winters (usually with moderate to heavy snowfall) and dry summers. Average annual precipitation in the valley is 100–300 mm, mostly occurring during winter and early spring in the form of snow. The vegetation of area falls in dry temperate coniferous forest containing the natural

Muhammad Shahid Iqbal, Abdul Nasir Khalid (2024) *Lecanora darelensis*, a new species of Lecanoraceae from Darel Valley, Gilgit Baltistan, Pakistan. *Telopea* 27: 117–124. doi:10.7751/telopea17708

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forests which mainly consist of *Cedrus deodara* (Roxb.) G.Don, *Pinus wallichiana* A.B.Jacks., *Abies pindrow* (Royle ex D.Don) Royle, *Fraxinus xanthoxyloides* (G.Don) Wall. ex DC. and *Pinus gerardiana* Wall. ex D.Don (Khan *et al*. 2013).

To date, 32 species of *Lecanora* have been reported from Pakistan (Aptroot & Iqbal 2010). All previously recognised species of *Lecanora* in Pakistan have been identified solely on morphological characters, so this is the first study of this genus to include a phylogenetic analysis. A new species *Lecanora darelensis* sp. nov. from Darel Valley has been described in this paper. The present work contributes molecular data on the genus *Lecanora* from Darel Valley and adds to our knowledge of *Lecanora* in Pakistan. Phylogenetic analyses assist in determining relationships of a *Lecanora* species collected from Pakistan, with those collected from other geographical areas of the world. Moreover, this research provides a baseline for future investigation on *Lecanora* taxonomy and diversity in Pakistan.

Materials and Methods

Morphological and chemical studies

Surveys were carried out in August and October 2022 in Darel Valley, Gilgit Baltistan, as a component of the corresponding author's PhD study project. Iqbal & Khalid (2024) provide additional details of the sample location. A stereomicroscope (Meiji Techno, EMZ-5TR, Japan) was used to study the morphological features of the thallus and apothecial discs. A compound microscope (MX4300H, Meiji Techno Co., Ltd., Japan) was used to measure a free-hand sections of the apothecia on a water–mounted glass slide. Standard microscopy and secondary chemistry was analysed using spot tests, which were performed using KOH (10%; K) and sodium hypochlorite solution (C). Thin Layer Chromatography was carried out using Solvent System C, following standard methods (Orange *et al*. 2010).

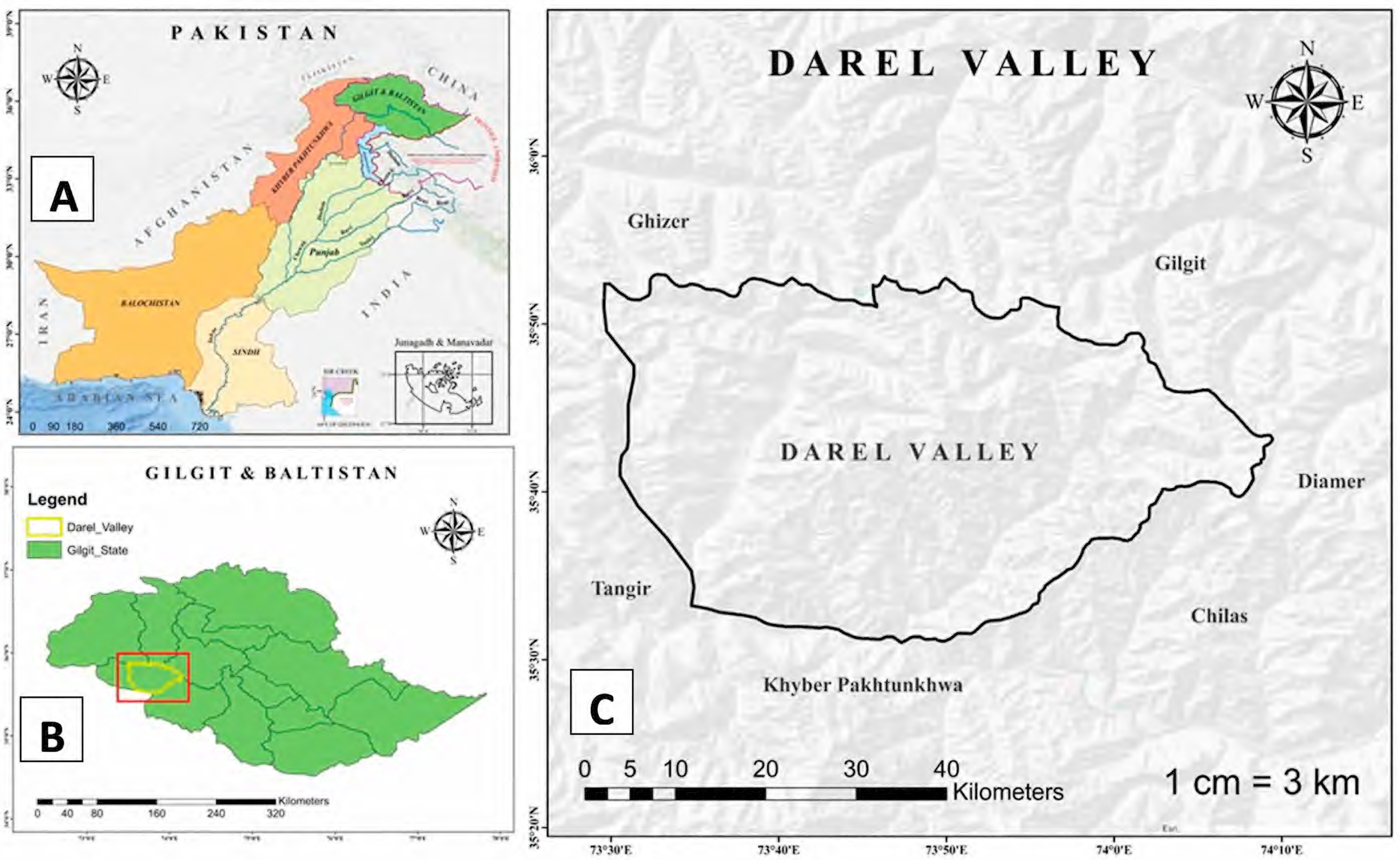

Fig. 1. Maps of sampling site. **A.** Pakistan. **B.** Gilgit Baltistan. **C.** Darel Valley.

Molecular Characterization

Nuclear DNA was extracted in the Fungal Biology and Systematics Research Laboratory, Institute of Botany, University of the Punjab from air dried and cleaned thalli using a GF1 Plant DNA extraction kit, as directed by the manufacturer (Vivantis, Selangor Darul Ehsan, Malaysia). For qualitative examination of total extracted DNA, 1% agarose gel electrophoresis was employed (Voytas 2000). PCR amplification of the ITS region was performed on a Bio-RAD T100 thermal cycler. Primers used during amplifications were ITS1F 50 -CCT GGT CAT TTA GAG GAA GT A A-3 0 and ITS4 50 -TCC GCT CTA TTG ATA TGC-30 for the ITS region (White *et al*. 1990; Gardes & Bruns 1993). Usman *et al* (2021) adopted the PCR conditions used by Gardes & Bruns (1993) and these modified PCR conditions were used here. PCR products were purified using a QIAquick PCR Purification Kit (Qiagen, Valencia, CA, USA) and then submitted to TsingKe, China for Sanger sequencing utilizing the aforesaid ITS1F, ITS4 amplicons for forward and reverse sequencing. To reconstruct forward and reverse sequences, the BioEdit sequence alignment editor was utilized (Hall 1999). The nucleotide sequence comparison was carried out using the National Centre for Biotechnology Information's (NCBI) Basic Local Alignment Search Tool (BLAST; Altschul *et al*. 1990). MAFFT v.7 was used

for the multiple sequence alignment, with all parameters set to default levels (Katoh & Standley 2013).

For phylogenetic analyses, the ITS gene was amplified and sequenced successfully from two Pakistani *Lecanora* collections (voucher no. LAH38235 & LAH38236) that yielded a fragment length of 600–650 base pairs each. Phylogenetic relationships were investigated using Maximum Likelihood bootstrapping, as implemented in RAxML–HPC2 v. 8.1.11 (Stamatakis 2014), hosted on the CIPRES Science Gateway (Miller *et al*. 2010). Analyses used rapid bootstrapping with 1,000 replications, and Kimura 2 (+G) parameter model. FigTree v 1.4.3 (Rambaut *et al*. 2014) was used for visualising trees from the ML analysis and preparing the figure. *Protoparmeliopsis garovaglii* (Körb.) Arup, Zhao Xin & Lumbsch was selected as an outgroup, for rooting the tree.

Results

Phylogenetic analysis

A total of 43 ITS nrDNA sequences were analysed, including two from Pakistan. The data matrix had 606 unambiguously aligned nucleotide positions among which 305 were constant, 280 variable sites, 246 were parsimony-informative and 32 were singleton variants. In our phylogram, our novel Pakistani samples (OR539699 & OR539700) formed a well–supported (74%) sister relation to *L. argopholis* (Ach.) Ach. from Austria, China and Russia (MN905177, MW257122 & MH512978).

Table 1. Comparison of characters between *Lecanora* species.

Characters	*Lecanora darelensis* sp. nov.	*L. argopholis*	*L. frustulosa*	*L. expallens*	*L. paramerae*	*L. substerilis*
Upper surface	pale yellowish green	yellowish white	pale cream yellow to yellowish white	mostly green or pale-yellow	whitish grey to greenish grey	grey
Apothecia	0.5–1.5 mm	1.2 mm	1.0 mm	1.0 mm	1.5–2.5 mm	1 mm
Apothecial Disc	brown, plane to convex, pruinose to rarely epruinose	deep yellowish brown, plane or slightly concave, epruinose	dark brown, blackish brown, plane or slightly concave, epruinose	yellowish, rarely distinctly convex	pale brown, flat to concave, epruinose	brown, epruinose
Epihymenium	25–35 µm	20 µm	15–20 µm	-	-	-
Hymenium	110–150 µm	70-75 µm	50–70 µm	40–45 µm	60–70 µm	60–80 µm
Ascospores	14–18 × 5–8 µm	12.7 × 7.3 µm	12 × 5.3 µm	10–14 × 3.4–4.5 µm	12–15 × 7.5–10 µm	10–14 × 7–11 µm
Chemistry	atranorin	atranorin, epanorin, zeorin	acetone	usnic acid and zeorin	atranorin, 2’-O-methylperlatolic acid, and psoromic acid, chloroatranorin, and 2’O-demethylpsoromic acid	atranorin and roccellic acid
Ecology	calcareous rocks	rock surfaces, detritus, mosses, sloping siliceous and calcareous rocks, boulders, gravel	siliceous and sub-calcareous rocks	bark of trees	on old *Juniperus thurifera* trees	forests, woodlands, *Fagus sylvatica*, *Abies alba*
References	this paper	Vänskä 1984	Vänskä 1984	Bajpai *et al*. 2012	Martínez *et al*. 1999	Malíček *et al*. 2017

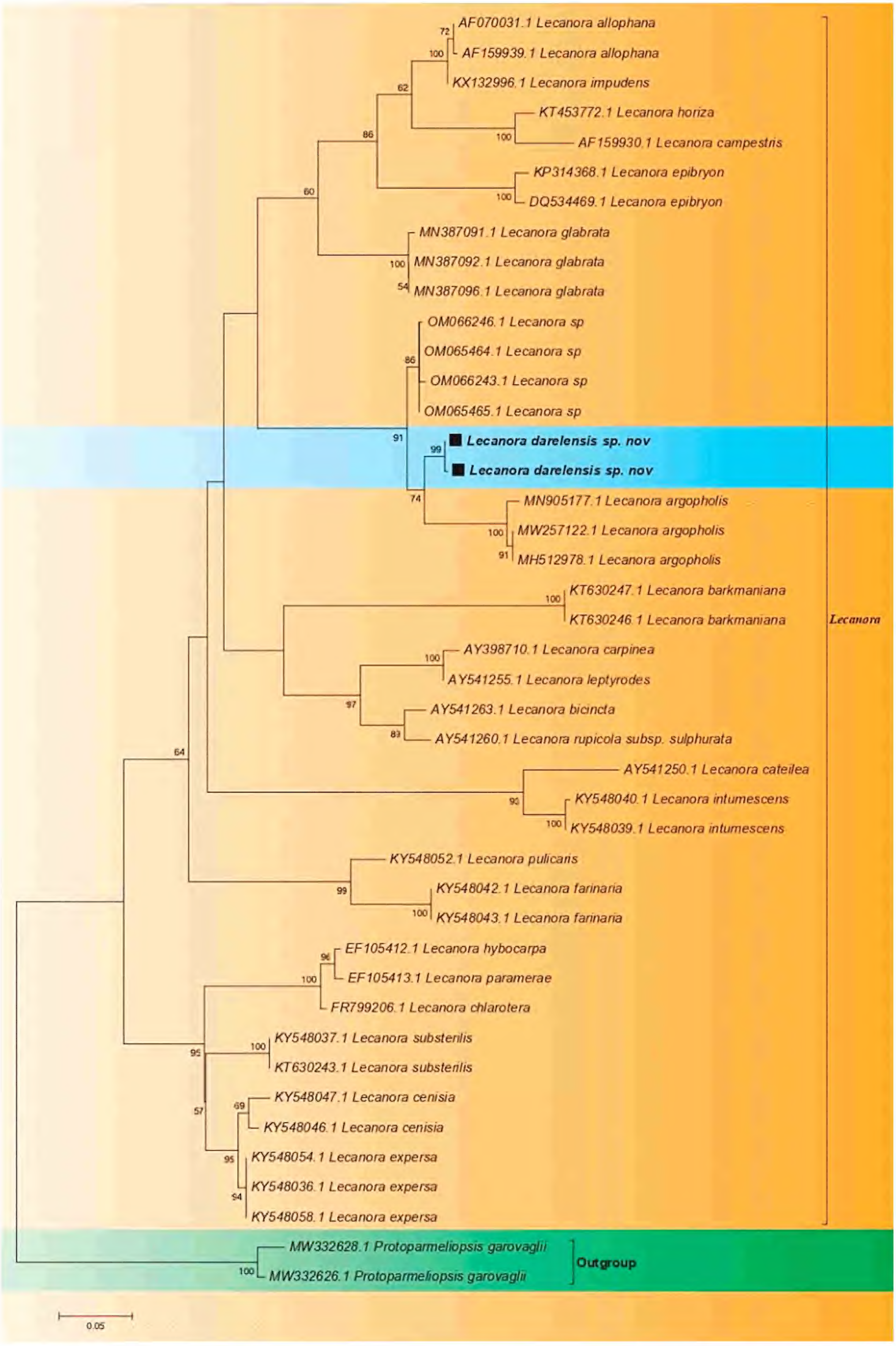

Fig. 2. Molecular phylogenetic analysis of *Lecanora* species using maximum likelihood methods, based on ITS1, 5.8S and ITS2 data. Numbers below branch node represent ML bootstrap (> 50%) based on 1,000 replicates. Sequences generated from Pakistani collections are marked with black box (■).

Taxonomy

Lecanora darelensis M.S.Iqbal & Khalid, *sp. nov.*

MYCOBANK # MB 849954

Holotype: PAKISTAN: Gilgit Baltistan, Darel Valley, 35°37'N, 73°27'E, 1,900 m, on rocks, 10 Aug, 2022, *Muhammad Shahid Iqbal DR–20* [ITS GenBank accession number OR539699] (holotype: LAH 38235).

Thallus: crustose, saxicolous, areolate, (0.5–)1–3(–5) cm across, (0.5–)0.8(–1) mm thick, loosely adnate to tightly adnate, pruinose, esorediate. **Areoles:** usually contiguous, plane to convex, flattened, smooth, matte, 0.2–0.7(–1) mm diam. **Upper surface:** pale yellowish green. **Cortex:** reddish brown to greyish reddish, (19–)25–45(–48) µm; crystals: hyaline, granular, dark brown, (3–)5.5(–7.5) × (2.5–)4(–5) µm, hyphae 2–3 µm diam. **Medulla:** 0.2–0.7(–1.0) µm thick. **Algal layer:** simple, countinous, (45–)50–110(–130) µm thick. **Algal cells:** *Trebouxia* type, cells subglobose to globose, (10–)14–22(–26) µm in diam. **Apothecia:** frequent at centre, dispersed, lecanorine. **Disc:** smooth, pruinose to rarely epruinose, plane to convex, glossy, brown, discrete to contiguous, (0.3–)0.5–1.5(3.5–) mm in diam. rounded to irregular with age. **Margins:** smooth, uneven, discontinuous, concolorous to thallus. **Thalline exciple:** containing algal cells. **Epihymenium:** light brown to dark greyish brown in KOH, (18–)25–35(–45) µm high. **Hymenium:** hyaline, (80–)110–150(–170) µm tall. **Hypothecium:** (45–)60–75(–90) µm tall, hyaline to light brown, containing algal cell in the lower part. **Paraphyses:** (1.5–)2.5–3.5(–4.5) µm thick, apically branched with capitate apices, (2.5–)3.7–4.5(–5) × (2–)2.8–3.2(–4) µm. **Asci:** clavate, *Lecanora*-type, (45–)55–65(–80) × (12–)16–21(–28) µm wide, 8-spored. **Ascospores:** aseptate, simple, hyaline, ellipsoid to sub-ellipsoid, (11–)14–18(–22) × (3–)5–8(–11) µm. **Conidiomata:** pycnidial, hyaline to pale brown walls, immersed, (8–)10–23(–27) µm thick. **Conidia:** simple, filiform, hyaline, bacilliform, (14–)17(–19.5) µm × 0.3 µm.

Chemistry: thallus and apothecial margin; K+ (bright yellow), C–, KC–. TLC: atranorin.

Diagnosis: The new taxon is phylogenetically closely related to *L. argopholis*. The former can be distinguished from latter in having pale yellowish green upper surface (vs yellowish white), larger apothecial disc 0.5–1.5 mm (vs 1.2 mm), brown, plane to convex, pruinose to rarely epruinose apothecial disc (vs deep yellowish brown, plane or slightly concave, epruinose), taller epihymenium 25–35 µm (vs 20 µm), taller hymenium 110–150 µm (vs 70–75 µm), larger ascospores 14–18 × 5–8 µm (vs 12.7–7.3 µm), atranorin is detected by TLC (vs atranorin, epanorin, zeorin) and growing on calcareous rocks (vs rock surfaces, detritus, mosses, sloping siliceous and calcareous rocks, boulders, gravel).

Habit and Habitat: found on calcareous rocks, collected from cold semi–arid climate at an altitude of 2,000 m a.s.l. The climate has typically cold desert characteristics, with severe winters (usually with moderate to heavy snowfall) and dry summers. Average annual precipitation in the valley is 100–300 mm, mostly occurring during winter and early spring in the form of snow. Common associated species are trees and shrubs, including *Pinus gerardiana*, *Cedrus deodara*, *Pinus wallichiana* and *Fraxinus xanthoxyloides*.

Additional specimen examined: PAKISTAN: Gilgit Baltistan, Darel Valley 34°36'N, 72°26'E, 1,843 m, on rocks, 10 Oct, 2022, *Muhammad Shahid Iqbal DR–26* [ITS GenBank accession number OR539700] (LAH 38236).

Etymology: The epithet *darelensis* refers to the type locality Darel, GB, Pakistan.

Discussion

Lecanora darelensis is phylogenetically closely related to *L. argopholis* (Ach.) Ach. The former can be distinguished from latter in having pale yellowish green upper surface (vs yellowish white), larger apothecial disc 0.5–1.5 mm (vs 1.2 mm), brown, plane to convex, pruinose to rarely epruinose apothecial disc (vs deep yellowish brown, plane or slightly concave, epruinose), taller epihymenium 25–35 µm (vs c. 20 µm), taller hymenium 110–150 µm (vs 70–75 µm), larger ascospores 14–18 × 5–8 µm (vs12.7 × 7.3 µm), atranorin is detected by TLC (vs atranorin, epanorin and zeorin) and growing on calcareous rocks (vs rock surfaces, detritus, mosses, sloping siliceous and calcareous rocks, boulders, gravel) (see Vänskä 1984).

The new taxon differs from *L. frustulosa* (Dicks.) Ach. in having pale yellowish green upper surface (vs pale cream yellow to yellowish white), larger apothecial disc 0.5–1.5 mm (vs c. 1.0 mm), brown, plane to convex, pruinose to rarely epruinose apothecial disc (vs dark brown, blackish brown, plane or slightly concave, epruinose), taller epihymenium 25–35 µm (vs 15–20 µm), taller hymenium 110–150 µm (vs 50–70 µm), larger ascospores 14–18 × 5–8 µm (vs c. 12 × 5.3 µm), atranorin is detected by TLC (vs acetone) and growing on calcareous rocks (vs siliceous and sub-calcareous rocks) (see Vänskä 1984).

Our new species can be distinguished from *L. expallens* Ach. in having pale yellowish green upper surface (vs mostly green or pale-yellow), larger apothecial disc 0.5–1.5 mm (vs 1.0 mm), brown, plane to convex, pruinose to rarely epruinose apothecial disc (vs yellowish, rarely distinctly convex), taller hymenium 110–150 µm (vs 40–45 µm), larger ascospores 14–18 × 5–8 µm (vs 10–14 × 3.4–4.5 µm), atranorin is detected by TLC (vs usnic acid and zeorin) and growing on calcareous rocks (vs bark of trees) (Bajpai *et al*. 2012).

Similarly, our new taxon is clearly differentiated from the *L. paramerae* in having pale yellowish green upper surface (vs whitish grey to greenish grey), smaller apothecial disc 0.5–1.5 mm (vs 1.5–2.5 mm), brown, plane to convex, pruinose to rarely epruinose apothecial disc (vs pale brown, flat to concave, epruinose), taller hymenium 110–150 µm (vs 60–70 µm), larger ascospores 14–18 × 5–8 µm (vs 12–15 × 7.5–10 µm) and growing on calcareous rocks (vs on old *Juniperus thurifera* trees) (see Martínez *et al*. 1999).

The new species also differs from *L. substerilis* Malíček & Vondrák in having pale yellowish green upper surface (vs grey), larger apothecial disc 0.5–1.5 mm (vs 1 mm), brown, plane to convex, pruinose to rarely epruinose apothecial disc (vs brown, epruinose), taller hymenium 110–150 µm (vs 60–80 µm), larger ascospores 14–18 × 5–8 µm (vs 10–14 × 7–11 µm) and growing on calcareous rocks (vs forests, woodlands, *Fagus sylvatica*, *Abies alba*) (see Malíček *et al*. 2017).

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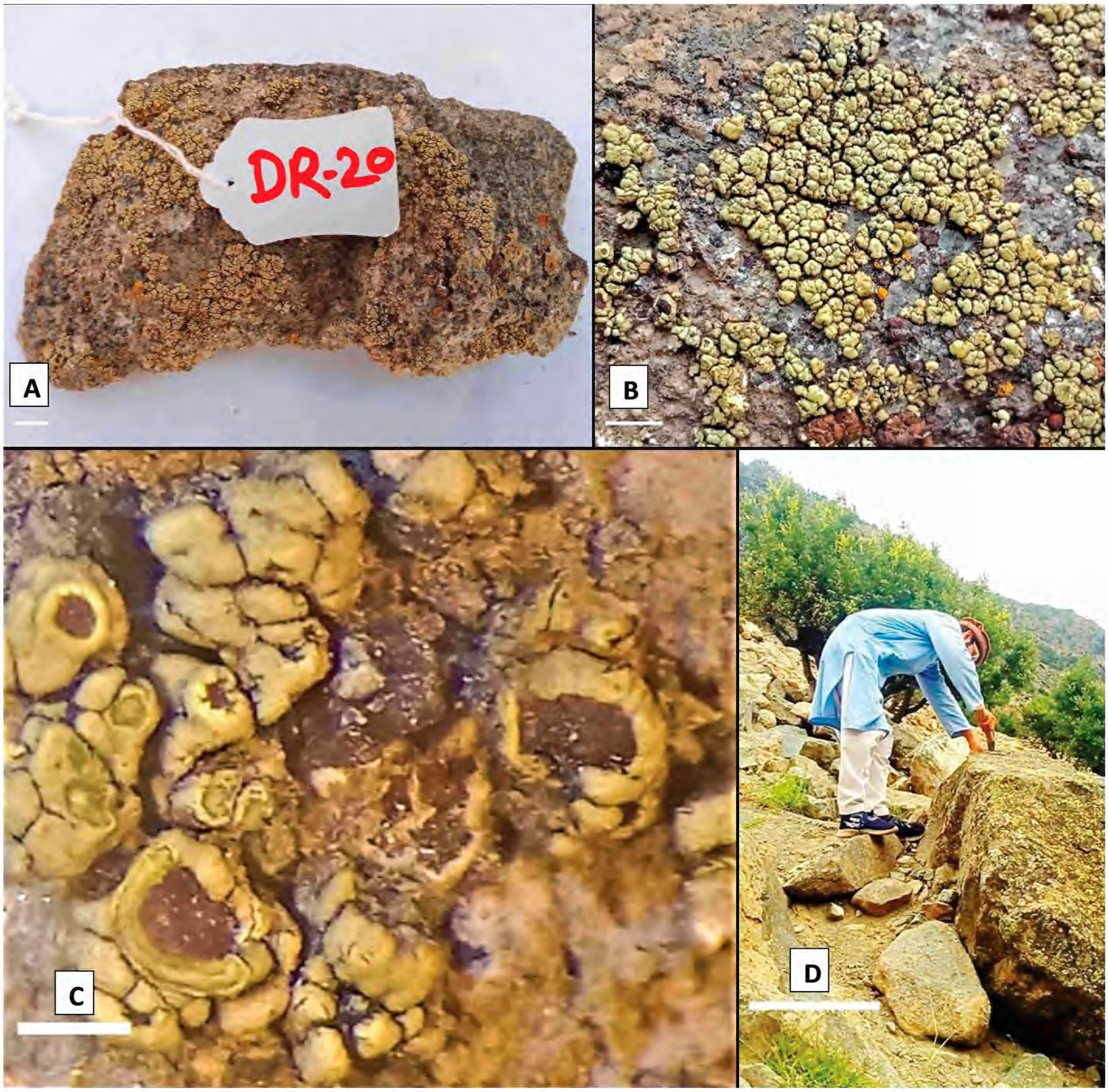

Fig. 3. *Lecanora darelensis*, sp. nov. **A, B.** Thallus. **C.** Apothecia. **D.** Author collecting lichens on rocks in the Darel Valley. Voucher: *M.S. Iqbal DR-20* (holotype: LAH 38235). Scale bars: A, B = 1 cm; C = 1.5 mm; D = 6 cm.

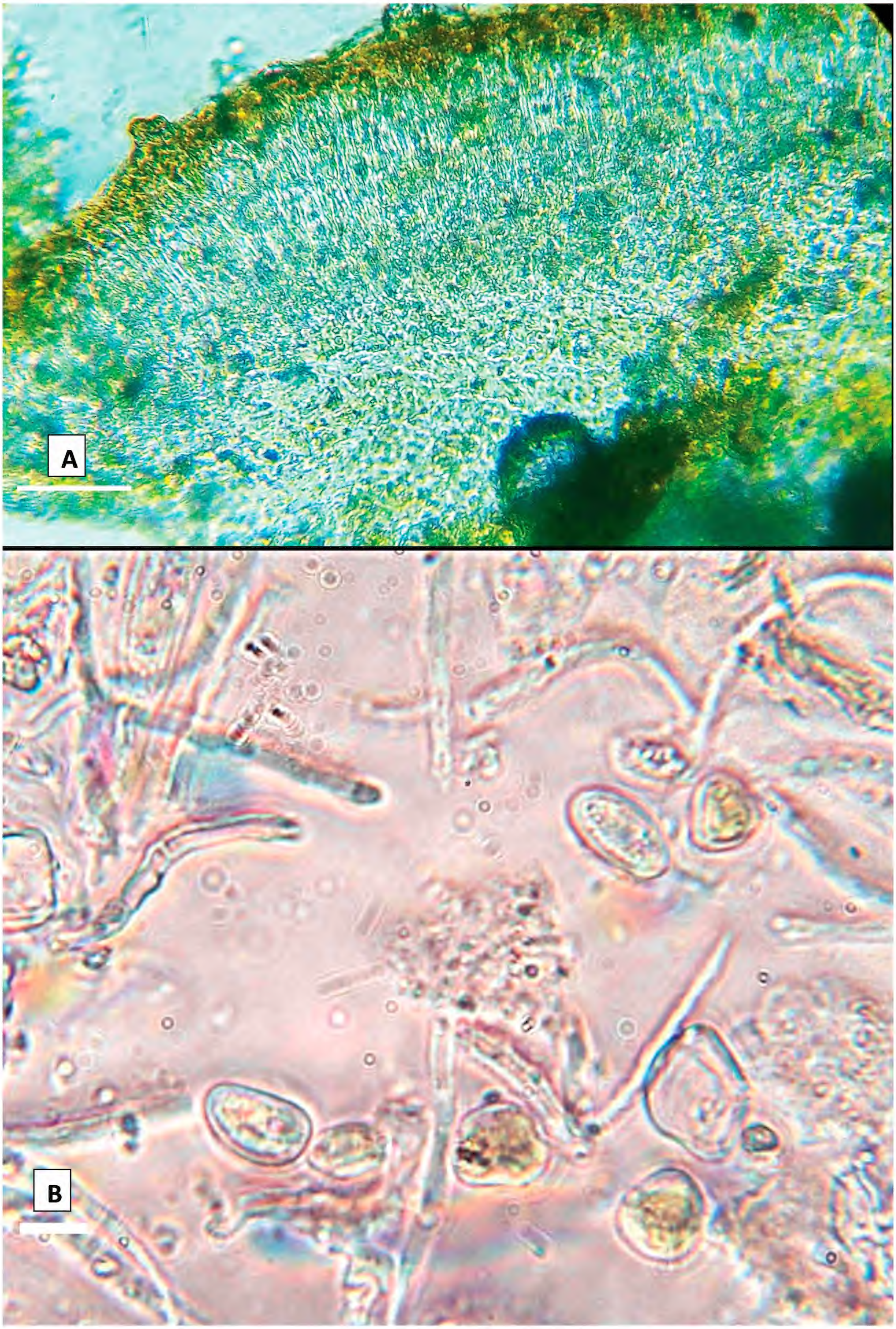

Fig. 4. *Lecanora darelensis*, sp. nov. **A.** Cross section of apothecium at 40 ×. **B**. Ascospores. Voucher: *M.S. Iqbal DR-20* (holotype: LAH 38235). Scale bars: A = 110 µm; B = 8 µm.

References

Altschul SF, Gish W, Miller W, Myers EW, Lipman DJ (1990) Basic Local Alignment Search Tool. *Journal of Molecular Biology*. 215(3): 403–410. DOI

Aptroot A, Iqbal SH (2010) Annotated checklist of the Lichens of Pakistan, with reports of new records. *Herzogia* 25: 211–229. DOI

Bajpai R, Upreti DK, Nayaka S, Dubey U (2012) Lichen flora in and around Mahabaleshwar, Satara district, Maharashtra with *Lecanora expallens* Ach., as new record to Indian lichen flora. *Phytotaxonomy* 12: 123–130.

Gardes M, Bruns TD (1993) ITS primers with enhanced specificity for basidiomycetes - application to the identification of mycorrhizae and rusts. *Molecular Ecology* 2(2): 113–118. DOI

Hafellner J (1984) Studien in Richtung einer natürlicheren Gliederung der Sammelfamilien Lecanoraceae und Lecideaceae. *Beihefte zur Nova Hedwigia* 79: 241–371.

Hall TA (1999) BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. In: *Nucleic acids symposium series* Vol. 41. pp. 95–98. (Information Retrieval Ltd: London)

Henssen A, Jahns HM (1974) *Lichenes*. (G.T. Verlag: Stuttgart)

Iqbal MS, Khalid AN (2024) *Diploschistes iqbalii* sp. nov. (Ascomycota: Graphidaceae), a new lichen species from Darel Valley, Gilgit Baltistan, Pakistan. *Nova Hedwigia*. DOI

Khan MZ, Khan B, Awan S, Khan G, Ali R (2013) High-altitude rangelands and their interfaces in Gilgit-Baltistan, Pakistan: Current status and management strategies. In Ning W, Rawat GS, Joshi S, Ismail M, Sharma E (eds), *High altitude rangelands and their interfaces in the Hindu Kush Himalayas*. pp 66–77. (International Centre for Integrated Mountain Development: Kathmandu, Nepal)

Katoh K, Standley DM (2013) MAFFT multiple sequence alignment software version 7: improvements in performance and usability. *Molecular Biology and Evolution* 30(4): 772–780. DOI

LaGreca S, Lumbsch HT (2001) Three species of *Lecanora* new to North America, with notes on other poorly known lecanoroid lichens. *The Bryologist* 104(2): 204–211.

Lücking R, Hodkinson BP, Leavitt SD (2017) The 2016 classification of lichenized fungi in the Ascomycota and Basidiomycota – approaching one thousand genera. *The Bryologist* 119(4): 361–416. DOI

Malíček J, Berger F, Palice Z, Vondrak J (2017) Corticolous sorediate *Lecanora* species (Lecanoraceae, Ascomycota) containing atranorin in Europe. *The Lichenologist* 49(5): 431–455. DOI

Martínez I, Aragón G, Lumbsch HT (1999) *Lecanora paramerae*, a new lichen from Spain. *The Lichenologist* 31(4): 315–318. DOI

Miller MA, Pfeiffer W, Schwartz T (2010) Creating the CIPRES Science Gateway for inference of large phylogenetic trees. In: *Proceedings of the Gateway Computing Environments Workshop* (GCE), 14 November 2010, New Orleans, LA. pp. 1–8. (IEEE Computer Society) DOI

Orange A, James PW, White FJ (2010) *Microchemical methods for the identification of lichens*. 2nd edn. (British Lichen Society: London) PDF

Rambaut A, Suchard MA, Xie D, Drummond AJ (2014) FigTree 1.4.2 software. (Institute of Evolutionary Biology, University of Edinburgh: Edinburgh) URL

Stamatakis A (2014) RAxML version 8: a tool for phylogenetic analysis and post–analysis of large phylogenies. *Bioinformatics* 30(9): 1312–1313. DOI

Usman M, Dyer PS, Khalid AN (2021) A novel arctic-alpine lichen from Deosai National Park, Gilgit Baltistan, Pakistan. *The Bryologist* 124(4): 484–493. DOI

Vänskä H (1984) The identity of the lichens *Lecanora frustulosa* and *L. argopholis*. *Annales Botanici Fennici* 21(4): 391–402. URL

Voytas D (2000) Agarose gel electrophoresis. *Current Protocols in Molecular Biology* 51: 2–5. DOI

White TJ, Bruns T, Lee SJWT, Taylor J (1990) Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. *PCR protocols: a guide to methods and applications* 18(1): 315–322. DOI

Zahlbruckner AV (1926) Lichenes (Flechten). B. Spezieller Teil. *Die natürlichen Pflanzenfamilien* 8: 61–270.

BOTANIC GARDENS OF SYDNEY

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The genus *Kania* (Myrtaceae, Kanieae) in the Philippines

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Abstract

A review of the Philippine species of *Kania* Schltr. (Myrtaceae, Kanieae) is presented, including the description of a new species, *Kania allochroa* Fernando & Peter G.Wilson. *Tristania microphylla* Quisumb & Merr. (*Kania microphylla* (Quisumb. & Merr.) Peter G.Wilson) and *Photinia urdanetensis* Elmer (*Kania urdanetensis* (Elmer) Peter G.Wilson) are lectotypified.

Introduction

Kania Schltr. is a genus of capsular-fruited species of Myrtaceae now placed in the monogeneric Tribe Kanieae Engl. with about 10 species and is, on present knowledge, restricted to New Guinea and the Philippines (Wilson *et al.* 2022). *Kania* is one of only a few genera in the Philippines with an East Malesian- or Papuasian-centred distribution pattern, approximately equivalent to distribution type 5b of van Balgooy (1971). The few genera that show a very similar pattern represent various families and include *Dolicholobium* (Rubiaceae) (Jansen and Ridsdale 1983), *Heterospathe* (Arecaceae) (Baker and Couvreur 2012), *Loheria* (Primulaceae) (Stone 1991), and *Sararanga* (Pandanaceae) (Stone 1961).

Kania is characterised by stamens arranged in a single whorl on the rim of the hypanthium, anthers with elongated connectives, and ovules with basal placentation (Wilson 1982). The two Philippine species were for a long time known only from their type collections until one of them was recollected recently. That species, *Kania microphylla* (Quisumb. & Merr.) Peter G.Wilson was first collected on Mt Alzapan, Nueva Vizcaya Province on Luzon Island nearly a century ago in May 1925. In July of 2023, the first author discovered this species growing on ultramafic substrate at low elevation near the southern end of the adjacent province of Isabela. The second species, *Kania urdanetensis* (Elmer) Peter G.Wilson, endemic to Mt Urdaneta on the northeastern part of Mindanao Island, has not been recollected since the type gathering in September 1912. In this paper, we review the genus as it occurs in the Philippines, update the descriptions of the two previously known species and designate lectotypes for them. Types were specified for both names but, according to the principles outlined by McNeill (2014), no holotype could be identified and so lectotypes were chosen in accordance with Art. 9.3 of the *International Code of Nomenclature* (Turland *et al.* 2018). The new species was discovered on ultramafic substrates on Mt Redondo, Dinagat Island, just north of Mindanao. We describe this species as *Kania allochroa* and provide notes on its ecology and conservation status.

Fernando ES, Quimado MO, Wilson PG (2024) The genus *Kania* (Myrtaceae, Kanieae) in the Philippines. *Telopea* 27: 125–133. doi:10.7751/telopea18212

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Materials and methods

All new material studied was collected by the first author. Initial observations were made on living material and confirmed and supplemented by additional measurements of dried herbarium specimens and inflorescences and flowers preserved in 70% ethanol. Characters in the descriptions were defined as in Beentje (2016). Herbarium acronyms follow Thiers (2024, updated continuously). To determine conservation status, we used the geospatial conservation assessment tool GeoCAT (Bachman *et al.* 2011; http://geocat.kew.org) to calculate the extent of occurrence (EOO) and area of occupancy (AOO) for the species as specified in the IUCN Red List Criteria and Categories (IUCN 2012) and IUCN Guidelines (IUCN Standards and Petitions Committee 2022).

Taxonomy

Kania allochroa Fernando & Peter G.Wilson, sp. nov.

Type: PHILIPPINES: Dinagat Island: Municipality of Loreto, Mount Redondo, 814 m elevation, in open dwarf forest on ultramafic soil, flower buds and open flowers, 12 Apr 2023, *E.S. Fernando 5348* (holotype: PNH; isotypes: LBC + spirit coll., NSW, PUH, SING).

Diagnosis: This species is most similar to *Kania urdanetensis* but differs in having thicker leaves with acute to obtuse, (vs. acuminate) apices and somewhat obscure secondary venation and flowers with longer petals (3–3.5 vs, c. 2.5 mm long) and styles (c. 4.5 vs c. 1.5 mm long).

Shrub or small *tree*, 3–5 m tall, glabrous; stem 5–10 cm diameter near the base; outer bark smooth to sparsely fissured-scaly; branches mostly upright; young twigs not distinctly angular. *Leaves* simple, opposite and decussate; petiole (2.5–) 3–6 (–7.5) mm long, c. 1.5–2.5 mm thick, more or less flat on the adaxial side, convex on the abaxial side; base obtuse to rounded; apex acute to obtuse; lamina coriaceous, broadly elliptic, rarely obovate or ovate, (15–) 20–35 (–37) mm long, (7–) 10–20 (–25) mm wide, the midrib very prominent on both surfaces; margins slightly thickened and revolute; the abaxial surface pubescent; secondary veins 12–20 on each side of the midrib, rather obscure on abaxial surface (*in vivo*), or distinct or faintly so on both surfaces (*in sicco*); intramarginal vein faintly visible on abaxial side, c. 0.3 mm from the margin; margin revolute; young leaves light reddish-brown, then pale white to green, to very densely white-pubescent on both surfaces, mature leaves glabrescent. *Inflorescence* a simple cyme or a compound dichasial cyme, axillary, 3–3.5 cm long, with up to 3–18 flower buds; peduncle 2–4 (–6) mm long, pubescent, sometimes subtended at base by leaf-like bracts, 2–3 mm long, 1–2 mm wide; frequently two inflorescences are produced per node, one in each axil; flower buds subglobose, *c.* 4 mm wide, densely pubescent, the petals and sepals imbricate in bud. *Flower* 5-merous, c. 7 mm wide when fully open; pedicel 1–2.5 mm long; sepals 3 mm long, 2–3 mm wide, spreading, the abaxial surface densely hairy, sepals persistent to fruiting stage; petals 3–3.5 mm long, 2.5 mm wide, pale pink-orange, turning to yellow or creamy-white with age, arrow-head (deltate) shape with a distinct basal part, the abaxial side pubescent along the midvein. *Stamens* 15–20, arranged in a continuous ring in front of the petals on the rim of the hypanthium, sometimes inequidistant from each other, but not distinctly grouped; filament 2–3.5 mm long, light yellow to white, more or less terete at the base and tapering apically; anther with prominent elongated connective, about as long as anther cells. *Ovary* subglobose, half-inferior, the free exposed part densely covered in brown indumentum, 3-locular; style terminal on the ovary, filiform, 4.5 mm long; stigma punctiform; placentation basal, ovules elongated (linear), anatropous, c. 9–11 per locule. *Fruit* a dry capsule, subglobose, 5 mm long, 7–8 mm wide, with sparse, appressed indumentum on the surface, 3-locular; calyx spreading, persistent; seed not known. Figures 1–2.

Distribution: Endemic to the Philippines. This species is, thus far, known only from the type locality on Mt Redondo, Dinagat Island.

Etymology: The epithet *allochroa* is from the (latinized) Greek, *allochrous*, meaning 'changed in colour', referring to the changing colour of the petals as the flower opens and matures (Figures 1D, E).

Habitat and ecology: This species occurs in dwarf, usually dense forest on ultramafic soil, 733–840 m elevation. The associated woody species in the habitat of this species include the widespread *Leptospermum amboinense* Blume (Myrtaceae), *Decaspermum sp.* (Myrtaceae), *Ixonanthes reticulata* Jack (Ixonanthaceae), *Psychotria surigaoensis* Sohmer & A.P.Davis (Rubiaceae), *Tristaniopsis flexuosa* Fernando & Peter G.Wilson (Myrtaceae), *Dacrydium beccarii* Parl. (Podocarpaceae), *Osmoxylon dinagatense* (Merr.) Philipson (Araliaceae), *Syzygium crassissimum* (Merr.) Merr. (Myrtaceae), *Croton leiophyllus* Müll. Arg. (Euphorbiaceae), and *Nepenthes mindanaoensis* Sh.Kurata (Nepenthaceae), among other plants. Shrubby plants of *Kania allochroa* at its type locality on Mt Redondo were seen to be flowering even when barely over a meter tall (Figure 1B). Fully mature trees tend to have rather dense crowns. *Kania allochroa* was observed to be flowering in April and fruiting in September.

Other specimens examined: Philippines. Dinagat Island: Municipality of Loreto, Mount Redondo, 733 m elevation, in dwarf forest on ultramafic soil, flower buds and open flowers, 12 Apr 2023, *E.S. Fernando 5335* (LBC, NSW, PNH, SING), *E.S. Fernando 5338* (LBC + spirit coll., PNH), 817 m elevation, flower buds, 12 Apr 2023, *E.S. Fernando 5356* (LBC), 840 m elevation, mature fruits, 29 Sep 2015, *E.S. Fernando 3837A* (LBC).

Notes: *Kania allochroa* is the sixth new species of flowering plant described from Mt Redondo since 2018. The five other species earlier described from this mountain include species in the genera *Medinilla* (Melastomataceae) (Fernando *et al.* 2018), *Nepenthes* (Nepenthaceae) (Robinson *et al.* 2019), *Tristaniopsis* (Myrtaceae) (Fernando and Wilson 2021), *Alpinia* (Zingiberaceae) (Docot *et al.* 2022), and *Vaccinium* (Ericaceae) (Tamayo *et al.* 2023). The Mt Redondo area on Dinagat Island has been, and remains, a mining concession but mining operations have been suspended since February 2017. Consequently, this site has only recently been accessible to botanists, with appropriate government permits, to undertake short term research on the flora. It is likely that many more species remain to be discovered in the dwarf forest on this small ultramafic mountain.

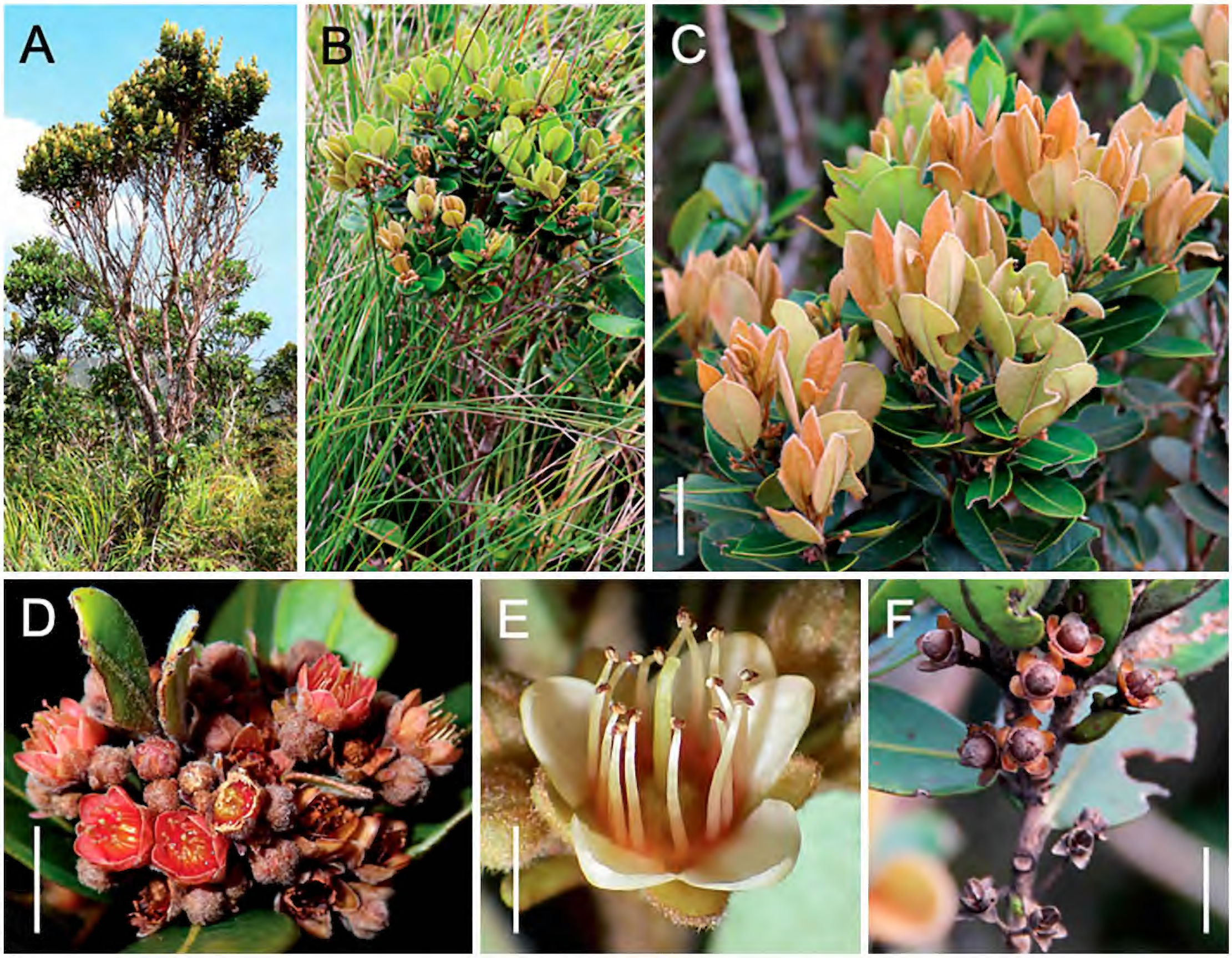

Figure 1. *Kania allochroa* Fernando & Peter G.Wilson. **A.** Tree at type locality showing growth habit. **B.** Small tree habit at just over a meter tall but already flowering, growing with the sedge *Machaerina disticha* (Cyperaceae). **C.** Branch showing young leaf growth. **D.** Cluster of flowers and flower buds with the newly opened flowers (bottom left of photo) showing pale pink-orange petals. **E.** Close up of fully opened flower with light yellow to creamy-white petals and stamens in a single whorl on the rim of the hypanthium showing anthers with elongated connectives. **F.** Fruiting branch showing mature, unopened fruits (top part of photo) with persistent sepals and dehisced fruits (bottom part of photo). A, D from *E.S. Fernando 5348*; B from *E.S. Fernando 5356;* E from *E.S. Fernando 5335;* F from *E.S. Fernando 3837A*. Scale bars: C = 30 mm; D, F = 10 mm; E = 3 mm. All photographs by Edwino S. Fernando.

Provisional conservation assessment: All collections of *Kania allochroa* cited here are only from five adjacent localities between 700 and 850 m elevation on Mt Redondo; no plants were recorded from lower slopes. Using the online GeoCAT conservation assessment tool (Bachman *et al.* 2011; http://geocat.kew.org), we calculated an Extent of Occurrence (EOO) below 100 km^2, which is within threshold for the category of Critically endangered (CR) and Area of Occupancy (AOO) of 20 km^2, within the threshold for the category of Endangered (EN). However, the entire summit area of the mountain is less than 6 km^2 (Lillo *et al.* 2019) and the species is known, thus far, only from this site. Although this whole area, including Mt Redondo and its adjoining Mt Kambinliw, is listed as a Key Conservation Site PH081 (Mallari *et al.* 2001), it remains within a mining concession and some parts of it have previously been dug open to mine for chromite. A continuing decline is inferred or projected in the (i) extent of occurrence; (ii) area of occupancy; and (iii) area, extent and/or quality of habitat due to the possibility of further mining and other development activities on site. Following IUCN (2012) and the *Guidelines for Using the IUCN Red List Categories and Criteria* (IUCN Standards and Petitions Subcommittee 2019), we regard this species as Critically Endangered CR B1ab(ii,iii)+2ab(i,ii,iii).

Kania microphylla (Quisumb. & Merr.) Peter G.Wilson, *Blumea* 28: 179 (1982).

Tristania microphylla Quisumb & Merr., *Philipp. J. Sci., Bot.* 36: 176 (1928).

Type: PHILIPPINES: Luzon Island: 'Nueva Vizcaya Province, Mt Alzapan', 'on slopes in the mossy forest', 1700 m elevation, 21 May 1925, *M. Ramos & G. Edaño BS 45613* (Lectotype: (designated here) UC [barcode UC329915]; isolectotypes A [A00071587], NTUF [F00004819], NY [NY03090993], P [P05227642], US [US118324]). Figure 3.

Small *tree*, 3 m tall, glabrous; stem c. 7 cm diameter near the base; outer bark with transverse ridges and randomly cracking in small pieces; branches mostly upright; young twigs or branchlets not distinctly angular, red-brown appressed-pubescent. *Leaves* simple, opposite and decussate; petiole (1–) 3–8 mm long, 1.2–2.0 mm thick; lamina subcoriaceous,

narrowly oblong-lanceolate to oblong-elliptic, (15–) 30–50 mm long, (6–) 10–25 mm wide, the abaxial surface pubescent; base cuneate to attenuate; apex acute to attenuate; secondary veins 16–24 on each side of the midrib, rather obscure on abaxial surface (*in vivo*), or distinct or faintly so on both surfaces (*in sicco*); intramarginal vein only faintly visible on adaxial surface, very close to margin; margin revolute; young leaves light reddish-brown, then pale green to green. *Inflorescence* a simple cyme, dichasial cyme, or thyrsoid, axillary, or sometimes appearing subterminal, 1.3–2.7 cm long, with up to 3–20 (–27) flower buds; flowers usually in triads, red-brown pubescent; peduncle 4–9.5 mm long; flower buds subglobose, pubescent, 2 mm diameter. *Flower* 5-merous, 4–6 mm wide when fully open; pedicel c. 2 mm long; sepals unequal, 1–1.5 mm long, pubescent; petals yellow, orbicular rounded, c. 2 mm long. *Stamens* 15–20, in a single series on the rim of the hypanthium, filament 1.5–2 mm long, anther connective about half the length of anther cells; glabrous, 2.0–2.25 mm long, 2.0–2.5 mm broad. *Ovary* half-inferior, 3-locular, the free, exposed part pubescent; style c. 2.5 mm long, stigma ± capitate; ovules anatropous, 12–17 per locule. *Fruit* not known.

Other specimen examined: Philippines: Luzon Island, Isabela Province, Dinapigue, c. 600 m elevation, in forest on ultramafic soil, 6 Jul 2023, *E.S. Fernando 5471* (LBC, PNH, PUH, NSW, SING).

Figure 2. *Kania allochroa* Fernando & Peter G.Wilson. **A.** Longitudinal section of flower bud showing basal placentation in ovary. **B.** Longitudinal section of open flower with sepals and petals removed also showing basal placentation in ovary. **C.** Transverse section of open flower with sepals and petals removed showing 3-locular ovary. **D.** Newly opened flower showing anthers with the elongated connectives. **E.** Flower with the sepals removed to show the deltate shape of petals when flat, the hairy abaxial surface along the midvein, and distinct attachment. A–E all from *E.S. Fernando 5348,* material in spirit collection. Scale bars: A–C = 2 mm; D–E = 3 mm. All photographs by Edwino S. Fernando

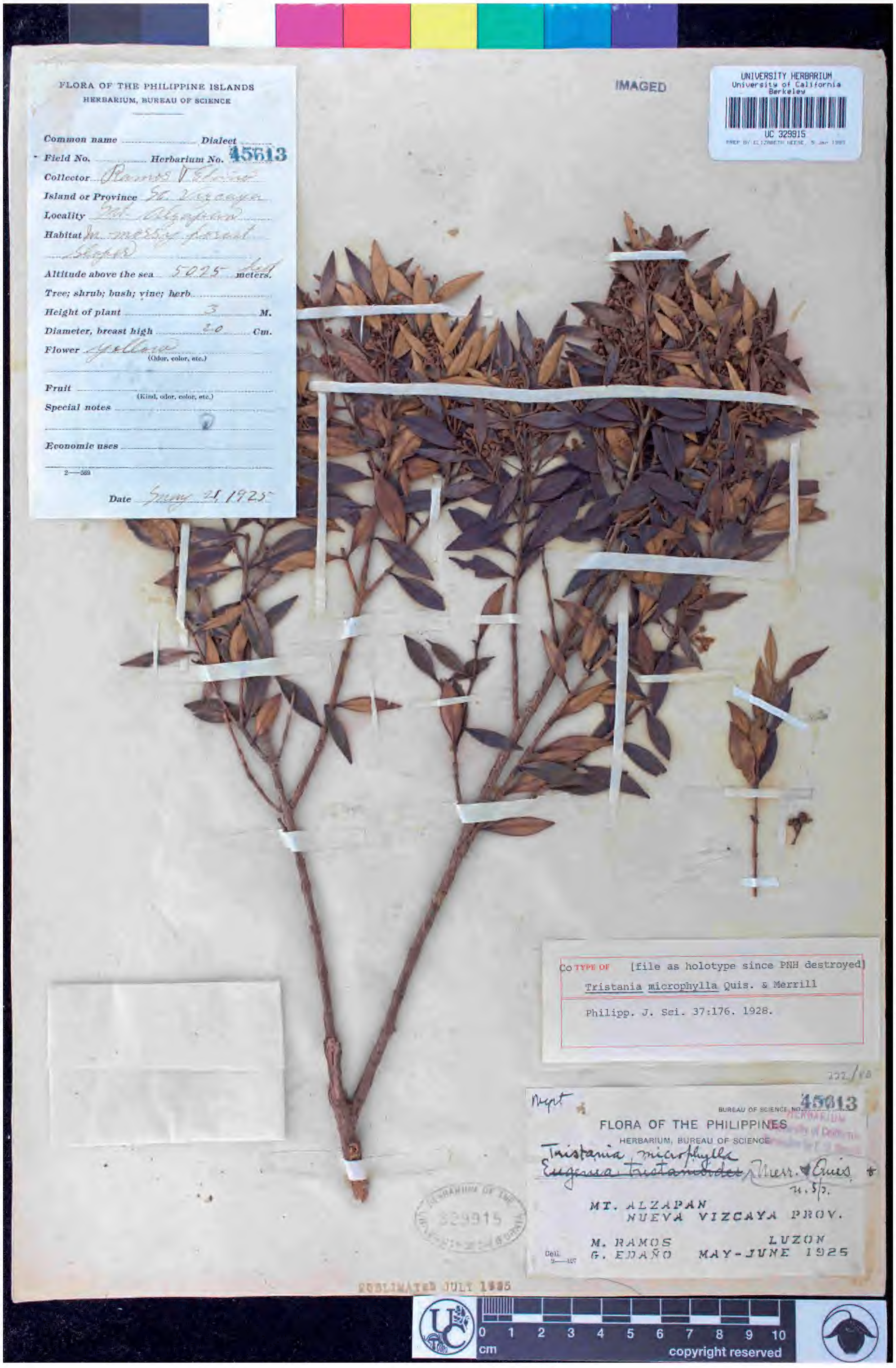

Figure 3. Lectotype of *Tristania microphylla* Quisumb. & Merr. (UC329915; reproduced courtesy of The University & Jepson Herbaria, University of California, Berkeley).

Typification: We have chosen the duplicate specimen at UC as lectotype because it bears Ramos and Edaño's original hand-written collection notes.

Notes: M. Ramos and G. Edaño, plant collectors from the then Bureau of Science, made collections on Mt Alzapan in May–June 1925. Herbarium labels for some of their collections place Mt Alzapan in Nueva Vizcaya Province (*e.g.* Quisumbing and Merrill 1928; Bramley 2013), while other collections of theirs place Mt Alzapan in Tayabas Province (*e.g.* Sohmer and Davis 2007; Cheek and Jebb 2013). Tayabas was officially renamed Quezon Province in 1946 and subsequently, in 1979, the northern part was segregated as Aurora Province and the southern part as Quezon Province. Unfortunately, the exact locality of Mt Alzapan remains uncertain; it is not currently shown on any Philippine map or gazetteer. The recent collection of *Kania microphylla*, cited above, was made at Dinapigue in the southeastern part of Isabela Province near the border with present-day Aurora Province. This location is certainly in the same general area where Ramos and Edaño made their collection.

Provisional conservation assessment: Apart from the two cited collections, there is a third, unvouchered, record of this species made by the first author (ESF) during an unplanned visit to the southern part of the national park at a time when he did not have a current permit. No collections were made but photographs were taken. This third site is also within the Municipality of Dinapigue and is approximately 5–6 km northwest of the second locality. The plants occurred in dwarf forest, also on ultramafic soil, well above 830 m on the summit plateau of the southern end of the Northern Sierra Madre Natural Park in an area dominated by *Leptospermum amboinense* Blume (Fernando and Quimado 2023). Since this site is within the natural park, this should provide the species with some protection. Since the precise location of Mt Alzapan is uncertain, the exact geographic extent of occurrence (EOO) of the species cannot be calculated. Therefore, we provisionally assign this species the category of Near threatened (NT) given the few known localities.

Kania urdanetensis (Elmer) Peter G.Wilson, *Blumea* 28: 179 (1982).

Photinia urdanetensis Elmer, *Leaflets Philipp. Bot.* 8: 2802 (1915).

Cloezia urdanetensis (Elmer) Merrill, *Philipp. J. Sci., Bot.* 14: 429 (1919).

Mooria urdanetensis (Elmer) Merrill, *Enum. Philipp. Fl. Plants* 182 (1923).

Type: PHILIPPINES: Mindanao Island: Mt Urdaneta, 'along a wind-swept cold and mossy ridge', c. 1670 m elevation, Sep 1912, *A.D.E. Elmer 13694*, Lectotype (designated here) UC [barcode UC271293]; Isolectotypes A [A00068963], A [A00068964], BISH [BISH576757], F [F422281], HBG [HBG511077], L [L0009524], MICH [MICH1111271], NA [NA27005], NSW [NSW94279], NY [NY436126], P [P03650699], U [U0005082], US [US00097506]). Figure 4.

Shrubby *tree*, 5 m tall or taller; branches ascending, flexuose, rigid, branching further towards the top; young twigs ridged or 4-angled, whitish to brownish appressed pubescent. *Leaves* simple, opposite and decussate; petiole mostly 2–4 mm long, c. 1.5 thick, more or less flat on the adaxial side, convex on the abaxial side; base obtuse or tapering to the petiole; apex acuminate; lamina elliptic to ovate, (22–) 30–50 mm long, (9–) 15–25 mm wide, subcoriaceous, the midvein ± level above, convex below; margins somewhat recurved; secondary veins 13–17 (–20), obscure above, distinct below; intramarginal vein visible on adaxial side, very close to the margin; young leaves discolorous, pubescent, yellowish-brown above, mature leaves glabrescent, dark green above, paler below. *Inflorescence* a cyme, dichasial cyme or thyrsoid, axillary, 8–17 mm long, with 3–15 flower buds; peduncle 3–4.5 (–6) mm long, yellowish-brown pubescent; frequently two inflorescences are c per node, one in each axil; flower buds subglobose, 2.5–3 (–4.5) mm wide, densely pubescent, the petals and sepals imbricate in bud. *Flowers* 5-merous, to c. 8 mm wide when fully open; pedicel 2–3 mm long; sepals c. 2 mm long, 3 mm wide, the abaxial surface pubescent; petals rounded, *c.* 2.5 mm long, 2.5 mm wide, the abaxial side pubescent along the midvein. *Stamens* 15–20, arranged in a ± continuous ring in front of the petals on the rim of the hypanthium, ± equally spaced; filament 1.5–3 mm long, glabrous, more or less terete at the base and tapering apically; anthers with a prominent elongated connective, as long as or slightly longer than the anther cells. *Ovary* subglobose, half-inferior, the free exposed part densely covered in brown indumentum, 3-locular; style set into a shallow pit on the ovary summit, filiform, c. 1.5 mm long; stigma punctiform; placentation basal, ovules anatropous, c. 12–15 per locule. *Fruit* unknown.

Typification: We have chosen the duplicate specimen at UC as lectotype because it includes a carbon copy of Elmer's field notes and description, is annotated by Merrill with both of his published synonyms, and clearly shows the inflorescences.

Notes: Mt Urdaneta, more currently referred as Mt Hilong-hilong, is also the Key Conservation Site PH083 and is home to the endemic Philippine eagle (Mallari *et al.* 2001), although it is not yet entirely a protected area. Part of this large mountain range between 200 and 1700 m elevation has been declared as the Cabadbaran–Santiago Natural Park, mainly as a watershed for the municipalities of Cabadbaran and Santiago in Agusan del Norte Province (Mallari *et al.* 2001). Mt Hilong-hilong is the type locality for many plant species, especially those collected by A.D.E. Elmer, including *Kania urdanetensis*. However, the mountain remains poorly explored for its plant diversity.

Provisional conservation assessment: This species is still known only from a single collection from its type locality on Mt Hilong-hilong. The Cabadbaran–Santiago Natural Park encompasses the elevation at which the type specimen was collected, and the species may possibly occur there. We provisionally assign this species the category of Near threatened (NT).

Figure 4. Lectotype of *Photinia urdanetensis* Elmer (UC271293; reproduced courtesy of The University & Jepson Herbaria, University of California, Berkeley).

Key to Species of *Kania* in the Philippines

1. Sepals up to 1.5 mm long; petals glabrous abaxially; anther connectives about half the length of anther cells ..... **K. microphylla**

1: Sepals 2 mm or longer; petals pubescent on abaxially; anther connectives about as long or longer than anther cells **2**

2. Leaf apex obtuse to acute or attenuate; petals 3–3.5 mm long; style 4.5 mm long ..... **K. allochroa**

2: Leaf apex acuminate; petals 2.5 mm long; style 1.5 mm long ..... **K. urdanetensis**

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References

Bachman S, Moat J, Hill AW, de la Torre J, Scott B (2011) Supporting Red List threat assessments with GeoCAT: geospatial conservation assessment tool. *ZooKeys* 150: 117–126. DOI

Baker WJ, Couvreur TLP (2012) Biogeography and distribution patterns of Southeast Asian palms. pp. 164–190 in Gower DJ et al. (eds), *Biotic Evolution and Environmental Change in Southeast Asia*. (Cambridge University Press: UK)

Beentje H (2016) *The Kew Plant Glossary*, 2nd ed. (Kew Publishing: Richmond, UK)

Bramley GLC (2013) The genus *Callicarpa* (Lamiaceae) in the Philippines. *Kew Bulletin* 68: 369–418. DOI

Cheek M, Jebb M (2013) *Nepenthes alzapan* (Nepenthaceae), a new species from Luzon, Philippines. *Phytotaxa* 100(1): 57–60. DOI

Docot RVA, Banag-Moran CI, Zamudio SGS, Tandang DN (2022) A revision of *Alpinia* sect. *Myriocrater* (Zingiberaceae) of the Philippines with a description of a new species. *Kew Bulletin* 77(2): 541–553. DOI

Fernando ES, Quakenbush JP, Lillo EP, Ong PS (2018) *Medinilla theresae* (Melastomataceae), a new species from ultramafic soils in the Philippines. *PhytoKeys* 113: 145–155. DOI

Fernando ES, Quimado MO (2023) *Ultramafic Flora of the Philippines: An Introduction to the Seed Plant Diversity on Philippine Ultramafics*. (University of the Philippines: Los Baños)

Fernando ES, Wilson PG (2021) *Tristaniopsis flexuosa* (Myrtaceae), a new species from ultramafic soils in the Philippines. *Telopea* 24: 345–349. DOI

IUCN (2012) *IUCN Red List Categories and Criteria*. Version 3.1, 2nd ed. (IUCN: Gland and Cambridge).

IUCN Standards and Petitions Subcommittee (2022) *Guidelines for Using the IUCN Red List Categories and Criteria*. Version 15.1. Prepared by the Standards and Petitions Subcommittee. PDF

Jansen ME, Ridsdale CE (1983) A revision of the genus *Dolicholobium* (Rubiaceae). *Blumea* 29: 251–311. URL

Lillo EP, Fernando ES, Lillo MJ (2019) Plant diversity and structure of forest habitat types on Dinagat Island, Philippines. *Journal of Asia-Pacific Biodiversity* 12: 83–105. DOI

McNeill, J (2014) Holotype specimens and type citations: General issues. *Taxon* 63: 1112–1113. DOI

Mallari NAD, Tabaranza BR Jr, Crosby MJ. (2001) *Key Conservation Sites in the Philippines*. (Bookmark: Makati City, Philippines)

Quisumbing E, Merrill ED (1928) New Philippine plants. *Philippine Journal of Science* 37(2): 133–213.

Robinson AS, Zamudio SG, Caballero RB (2019) *Nepenthes erucoides* (Nepenthaceae), an ultramaficolous micro-endemic from Dinagat Islands Province, northern Mindanao, Philippines. *Phytotaxa* 423: 21–32. DOI

Sohmer SH, Davis AP (2007) The genus *Psychotria* (Rubiaceae) in the Philippine Archipelago. *Sida*, *Botanical Miscellany* 27: 1–247.

Stone BC (1961) The genus *Sararanga* (Pandanaceae). *Brittonia* 13: 212–224. DOI

Stone BC (1991) The genus *Loheria* Merrill (Myrsinaceae). *Micronesica* 24(1): 65–80. URL

Tamayo MN, Fernando ES, Fritsch PW (2023) *Vaccinium coarctatum* (Ericaceae), an ultramafic-obligate new species from the dwarf forest of Mt Redondo, Dinagat Island, Philippines. *Edinburgh Journal of Botany* 80: e1960. DOI

Thiers BM (2024, updated continuously) *Index Herbariorum: A Global Directory of Public Herbaria and Associated Staff*. New York Botanical Garden's Virtual Herbarium. URL [Accessed 02 March 2024]

Turland NJ, Wiersema JH, Barrie FR, Greuter W, Hawksworth DL, Herendeen PS, Knapp S, Kusber W-H, Li D-Z, Marhold K, May TW, McNeill J, Monro AM, Prado J, Price MJ & Smith GF (2018) *International Code of Nomenclature for algae, fungi, and plants* (Shenzhen Code). *Regnum Vegetabile* 159. DOI

Van Balgooy MMJ (1971) Plant-geography of the Pacific. *Blumea* Suppl. 6: 1–222.

Wilson PG (1982) Additions to the genus Kania (Myrtaceae) in Malesia, with notes on Cloezia. *Blumea* 28: 177–180. URL

Wilson PG, Heslewood MM, Tarran MA (2022) Three new tribes in Myrtaceae and reassessment of Kanieae. *Australian Systematic Botany* 35(4): 279–295. DOI

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Notes on the type specimen of *Lepidium pseudopapillosum* (Brassicaceae) and its presence and conservation status in New South Wales, Australia

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Abstract

The holotype of *Lepidium pseudopapillosum* Thell. was previously thought to have been collected in New South Wales, Australia, and has been the only specimen lending credence to its occurrence in the state. A review of the type specimen has shown that this is not the case and that the location ascribed to the type in the protologue is in error. It is here posed that *L. pseudopapillosum* is restricted to South Australia and Victoria, and that in New South Wales this name has been misapplied to *L. ginninderrense* N.H.Scarlett. The conservation status on State and Commonwealth legislation should be amended to reflect this correction by removing *L. pseudopapillosum* from New South Wales conservation legislation but listing the species as endangered nationally.

Introduction

When Thellung (1917) first named and described *Lepidium pseudopapillosum* Thell., the type collection was cited as "Australien: Neu-Süd-Wales: Formbe, rocky lands, leg. E. Smith, VIII. 1902, sub nom. *L. papillosi* (Nat. Herb. of New South Wales; typus in herb. Univ. Zurich)". This resulted in the species being considered native to New South Wales (NPWS 2001; CHAH 2024) despite the locality of 'Formbe' never being properly identified and remaining unknown. This has raised the question as to whether the type *of L. pseudopapillosum* was actually collected in New South Wales (Hewson 1981; Scarlett 2001; DEWHA 2008; Scarlett and Hewson 2019).

Specimens subsequently collected from the Canberra area in the Australian Capital Territory (ACT) were tentatively described as *L. pseudopapillosum* (Retter and Harden 2000). However, these specimens were considered atypical for the species (Hewson 1981; Retter and Harden 2000), and were later described as a new species, *L. ginninderrense* N.H.Scarlett, considered endemic to the ACT (Scarlett 2001). With the exception of the ambiguously geolocated type specimen, no other specimen-backed record has been made for *L. pseudopapillosum* in New South Wales (OEH 2023; AVH 2024). The only confirmed specimens of *L. pseudopapillosum* are from the northern plains of Victoria and the Flinders Ranges in South Australia (Scarlett 2001; Scarlett and Hewson 2019).

Since the type of *L. pseudopapillosum* was considered to have been collected in New South Wales, and no other collections have been made since, the species was listed as Endangered in the New South Wales *Threatened Species Act 1995* and *Biodiversity Conservation Act 2016*. Uncertainty surrounding the exact locality of the type collection

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and a lack of any other record in New South Wales suggests that it is either extinct in New South Wales or that it was never present in the state (NPWS 2001). In a 2023 review of the species' threatened status in New South Wales, an ensuing hypothesis was established that, based on a likely typographical error, *L. pseudopapillosum* is not a native species in the state. The rationale in support of this, recommended removal of *L. pseudopapillosum* from the Schedules of the *Biodiversity Conservation Act 2016*, and the reconsideration of its Vulnerable status on the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* are presented below.

Re-appraisal of notes attached to the type specimen

Notes attached to the holotype of *L. pseudopapillosum* were accessed by downloading a high-resolution image of the specimen from the catalogue of Z+ZT (University of Zurich 2024). The original notes on the holotype (Fig. 1), as cited by Thellung (1917), are in the hand of Joseph Maiden, director of the National Herbarium of New South Wales (NSW) from 1896–1924. A comparison of the script on the *L. pseudopapillosum* type label with other correspondence made by Maiden in that period (Fig. 2) shows that the locality information on the type should be interpreted as 'Formby' rather than 'Formbe'. The former spelling was previously suggested by Scarlett and Hewson (2019), who indicated that the type might be from Formby Bay in South Australia, rather than anywhere in New South Wales. However, there may be a problem with this assumption, in that the collection dates to 1902, but the name 'Formby Bay' was not applied until 1908 (though it was possibly referred to by this name informally prior to being gazetted). There was a town named Formby in Tasmania at this time, which later merged with its sister town Torquay to become the current town of Devonport. The official merger occurred in 1890, but it appears the use of Formby as a location persisted for several decades. NSW does hold three lichen collections from Formby, Tasmania, collected by Francis Robert Muter Wilson in 1892, but no collections approach the details recorded on the *Lepidium* collection now at Z. No other locality known as 'Formby' is known to have been gazetted in Australia (ICSM 2024). However, several large properties were owned by the prominent South Australian Formby family in the Adelaide Hills area, including one known as 'Formby Park' (Dallwitz *et al.* 1985; Tucker and Crawford 2018), and this region is much more likely the source of the type specimen.

An incorrect association between the locality of Formby and New South Wales appears to have arisen from the pre-printed text 'N.S.W.' on the specimen label. Regular protocol with pre-printed labels was for the botanist lodging any specimen collected outside of the state to strike out the printed text 'N.S.W.' and then insert the correct state by hand. However, some contemporaneous specimens held at NSW (e.g. NSW4258) demonstrate that this sometimes did not happen, and that this manner of mis-labelling might have also occurred on the holotype of *L. pseudopapillosum*.

The above evidence supports that the holotype of *L. pseudopapillosum* was more likely collected from the Adelaide Hills in South Australia, partly supporting assertions of Scarlett and Hewson (2019) and DEWHA (2008). This finding means that *L. pseudopapillosum* is not known to be native to New South Wales.

Type citation

Lepidium pseudopapillosum Thell., *Vierteljahrsschr. Naturf. Ges. Zürich* 61: 462 (1916).

Type citation: "Australien: Neu-Süd-Wales: Formbe, rocky lands, leg. E. Smith, VIII. 1902, sub nom. L. papillosi (Nat. Herb. of New South Wales; typus in herb. Univ. Zurich)"

Type: [probably South Australia]: Formby [possibly 'Formby Park' OR Formby Road, Clarendon OR Kenton Valley], rocky lands, Aug. 1902, *E. Smith s.n.* (holo: Z 000005083).

Notes: While the collector is recorded as 'E. Smith', it is difficult to determine who this may have been. In the collections at Z, the collector's name is interpreted as Lindsay Stuart Smith (i.e. in this case the label information would indicate 'Esquire Smith'), though it is unclear how this conclusion was reached. Searching other collections by 'Smith' from 1902 reveals a collection of *Kennedia prostrata* by 'R. Smith' from the vicinity of Formby Bay on Yorke Peninsula (AD 97731402) and a collection of *Templetonia retusa* from the southern Yorke Peninsula (AD 97731401).

The common name of 'Formbe Peppercress' should be corrected to 'Formby Peppercress'.

Consequence for the threatened status of *Lepidium pseudopapillosum*

The threatened status for *L. pseudopapillosum* requires revision of both New South Wales and Commonwealth legislation based on the present finding that the species is not native to New South Wales. Section 4.3(1)(b) of the New South Wales *Biodiversity Conservation Act 2016* provides for flora to be listed as a threatened species only if they are "a species of plant that is native to New South Wales". Furthermore, its vulnerable status should also be reviewed on the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. No specimens of *L. pseudopapillosum* have been collected from South Australia since the 1902 Formby type collection, and only one other collection is known, from the Mt Lyndhurst region, northern Flinders Ranges in 1899 (MEL 1620694; see DEWHA 2008; Scarlett and Hewson 2019). It should be noted that this was originally a mixed collection and it remains possible that the locality is in error for this element, though the collector did live in the Mt Lyndhurst region at the time. Max Koch noted on several *Lepidium* collections from this area that they were favoured by sheep, and this may be the reason for the decline of *L. pseudopapillosum*.

The four extant populations occur in Victoria and are each highly restricted in abundance, which provides support to increase the species' conservation value and warrants assessment at a higher threat level. An endangered status under the IUCN Red List Criteria B2ab(iii, v) (IUCN 2024) is suggested since the maximum area of occurrence for the four threat-defined populations is approximately 46 km^2, and that there is a very high likelihood of continuing decline in the population due to habitat fragmentation. This listing level should also be adopted on the *Environment Protection and Biodiversity Conservation Act 1999*.

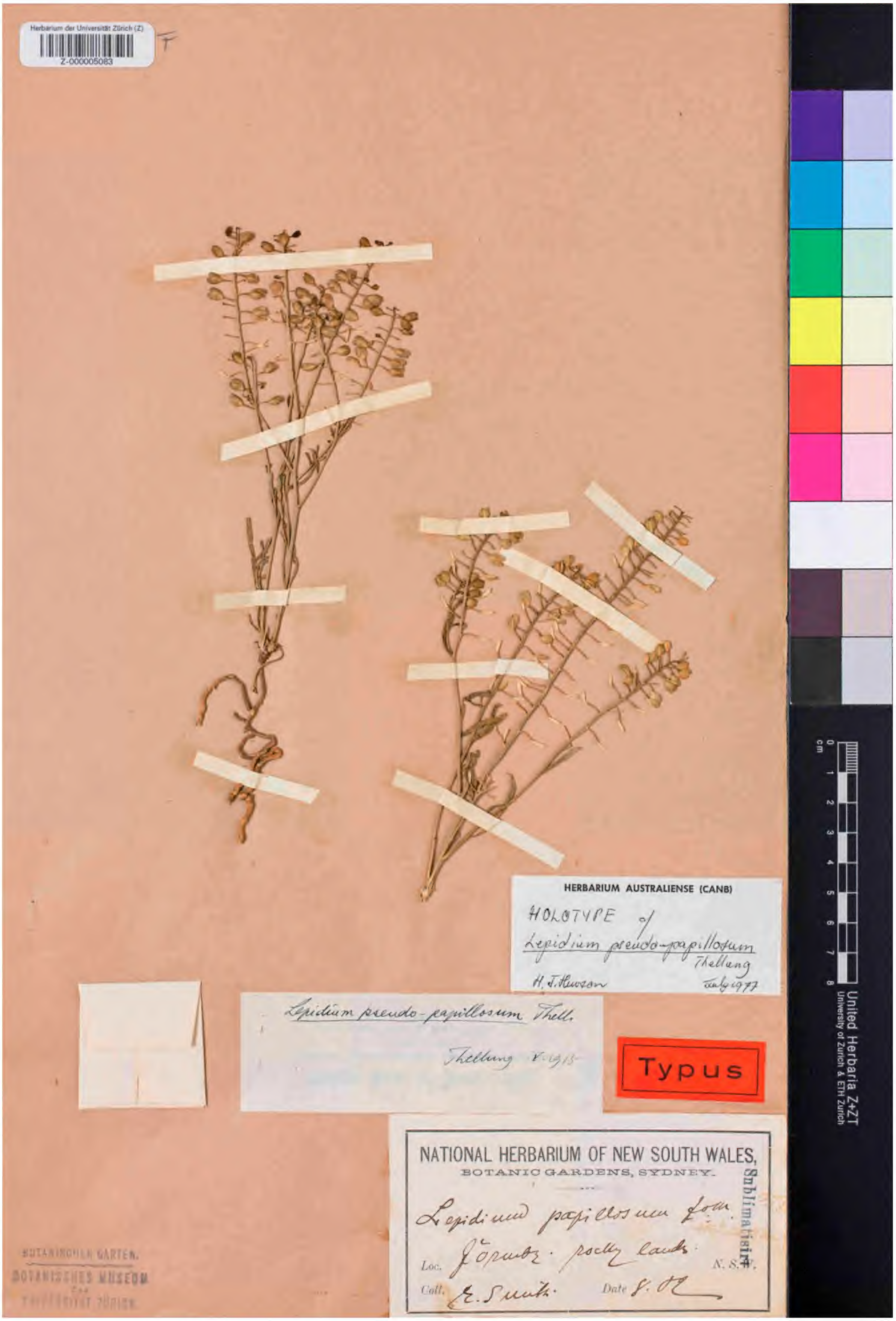

Figure 1. Holotype of *Lepidium pseudopapillosum* Thell. (Z-000005083 by United Herbaria Z+ZT / CC BY 4.0).

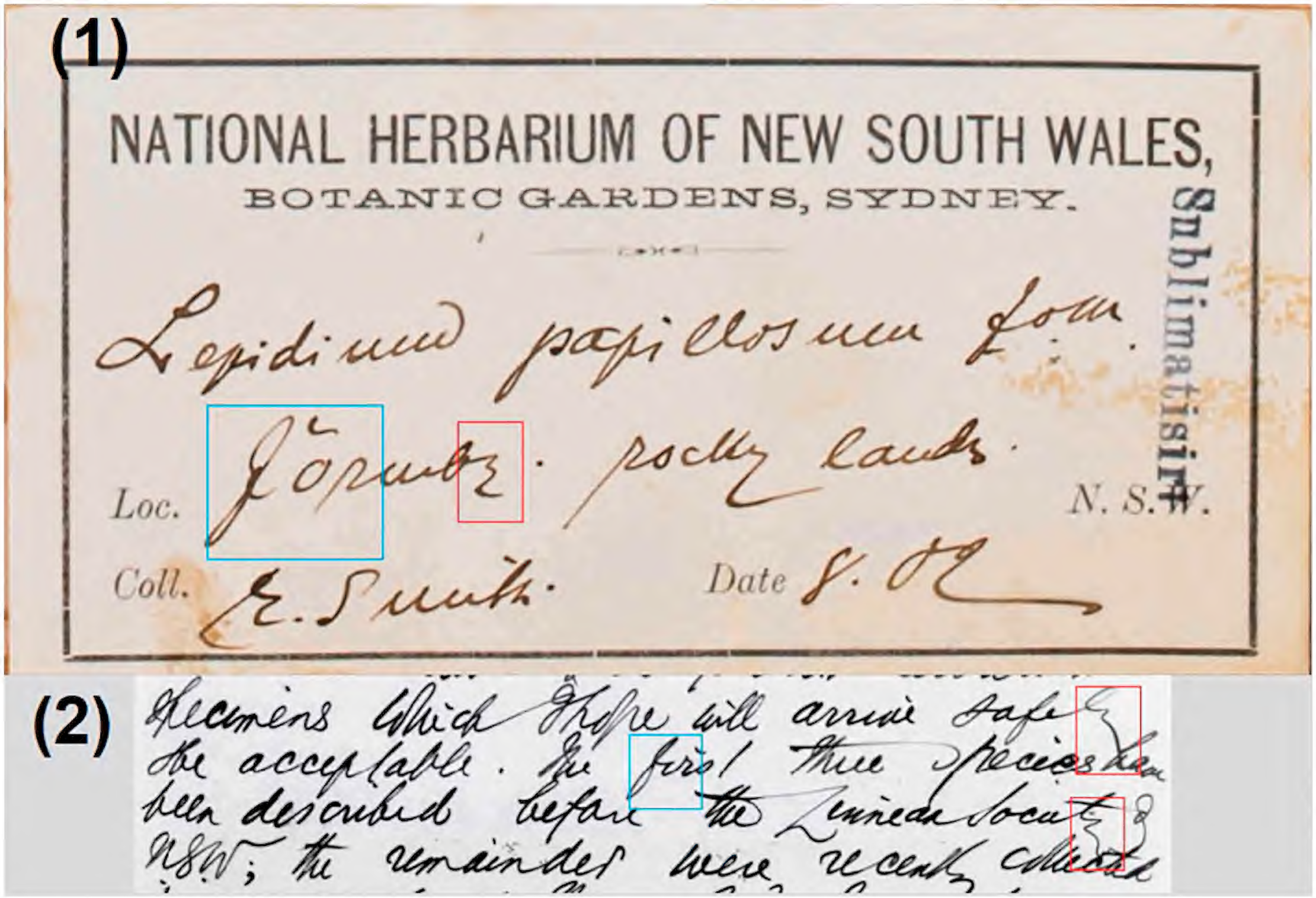

Figure 2. Comparison of (1) the holotype label of *Lepidium pseudopapillosum* (Z-000005083 by United Herbaria Z+ZT / CC BY 4.0); and (2) correspondence written by Joseph Maiden in 1898 (Royal Botanic Gardens, Kew & Australian Joint Copying Project & National Library of Australia & State Library of New South Wales 1950). Note the comparison of Maiden's handwriting of 'f' and 'r' (blue boxes), and 'y' (red boxes).

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References

CHAH (Council of Heads of Australian Herbaria) (2024) *Lepidium pseudopapillosum* in the Australian Plant Name Index URL: URL (accessed 23 April 2024)

AVH (Australian Virtual Herbarium) (2024) *Records of Lepidium pseudopapillosum*. URL (accessed 1 May 2024)

Dallwitz J, Marsden A, Marsden S, Linn R, Linn J (1985) *Heritage survey of the Fleurieu Peninsula. A report prepared for the State Heritage Branch of the Department of Environment and Planning by Heritage Investigations and Historical consultants Pty. Ltd.* PDF (accessed 12 July 2024)

DEWHA (Department of the Environment, Water, Heritage and the Arts) (2008) *Approved Conservation Advice for* Lepidium pseudopapillosum *(Erect Pepper-cress)*. PDF (accessed 23 April 2024)

Hewson HJ (1981) The genus *Lepidium* L. (Brassicaceae) in Australia. *Brunonia* **4**: 217–308. DOI

ICSM (Intergovernmental Committee on Surveying and Mapping) (2024) Composite Gazetteer of Australia. URL (accessed 23 April 2024)

IUCN (2024) Guidelines for Using the IUCN Red List Categories and Criteria. Version 16 (March 2024). Standards and Petitions Committee of the IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK.

OEH (Office of Environment and Heritage) (2023) Formbe Peppercress – profile. URL (accessed 23 April 2024)

Retter L, Harden GJ (2000) Brassicaceae. In: Harden GJ (ed), *Flora of New South Wales. Volume 1*. Revised edition. Pp. 459–486. (UNSW Press: Kensington)

Royal Botanic Gardens, Kew, Australian Joint Copying Project, National Library of Australia, State Library of New South Wales (1950). Records of the Royal Botanic Gardens, Kew (as filmed by the AJCP) [microform]: [M730-M788], 1793–1928. URL (accessed 3 May 2024)

Scarlett NH (2001) *Lepidium ginninderrense* (Brassicaceae), a new species from the Australian Capital Territory. *Muelleria* **15**: 69–74. DOI

Scarlett NH, Hewson HJ (2019) Brassicaceae (partly) (version 1). In Kellermann J (ed.), *Flora of South Australia* (ed. 5). 25 pp. (State Herbarium of South Australia: Adelaide) PDF

Thellung A (1917) III. Alabstra Diversa in Mitteilungen aus dem botanischen Museum der Universitat Zurich (LXXV). *Vierteljahrsschrift der Naturforschenden Gessellschaft in Zurich* **61**: 462–464.

Tucker C, Crawford A (2018) *Farms & homestead names and locations in the surrounding districts of Strathalbyn*. URL (accessed 12 July 2024)

University of Zurich (2024) Search specimens in the herbaria Z+ZT and ZSS: *Lepidium pseudopapillosum Thell.* URL (accessed 23 April 2024)

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A nomenclatural history for *Dendrobium* × *delicatum* (Orchidaceae)

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Abstract

The nomenclatural history of the naturally occurring hybrid orchid *Dendrobium* × *delicatum* (F.M.Bailey) F.M.Bailey is reviewed. The earliest published name for this hybrid was *D. speciosum* var. *delicatum* F.M.Bailey in 1883. In 1896, an artificially raised plant of *D. speciosum* × *D. kingianum* was granted an Award of Merit by the Royal Horticultural Society. Reports of this award in Horticultural periodicals that year were associated with publication of several names for the hybrid plants that only partially fulfilled the requirements of the *International Code of Nomenclature for plants, algae, and fungi* (ICN) and the *International Code of Nomenclature for Cultivated Plants* (ICNCP). None, however, achieved valid publication or establishment under the respective codes, leaving *Dendrobium* × *delicatum* (F.M.Bailey) F.M.Bailey as the earliest available name at species rank for the naturally occurring hybrid, contrary to recently published arguments that *D. speciokingianum* is the 'correct' name for both nothospecies and grex. The provisions of both ICN and ICNCP are discussed with reference to published names. The earliest name established for the grex is either D. Kingiano-speciosum or *D.* × *spyersii*. There seems nothing to be gained in having two names in Latin form for the same hybrid, when differences in origin can be reflected by typographical modification of the nothospecies epithet, as is current established practice.

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Introduction

A naturally occurring hybrid between *Dendrobium kingianum* Bidwill ex Lindl. and *D. speciosum* Sm. occurs sporadically along the south-east coast of Australia. This natural hybrid is patchily distributed, coincident with where the two parental species grow in close proximity. While the hybrid is generally uncommon, Alum Mountain near Bulahdelah and Spring Bluff near Toowoomba are celebrated localities where, even today, natural hybrids may be observed in the wild.

Like all *Dendrobium* sect. *Dendrocoryne* from south-east Australia, the hybrids between *D. kingianum* and *D. speciosum* attracted early attention from orchid taxonomists and orchid growers in nearly equal measure, both within Australia and overseas in England, to where plants were sent for cultivation by orchid enthusiasts.

This nomenclatural history is presented in two parts to reflect contributions to the naming of the hybrid from these different sources, scientific on the one hand and horticultural on the other. This subdivision also reflects the fact that names for hybrids are potentially, and in many cases actually, governed by two complementary

International Codes of Nomenclature, the *International Code of Nomenclature for plants, algae and fungi* (Turland et al. 2018) for wild plants on the one hand, and the *International Code of Nomenclature for Cultivated Plants* (Brickell et al. 2016) for cultivated plants on the other. Throughout this review, these codes are referred to as the ICN and ICNCP, respectively. The scientific contributions to naming of the natural hybrids made under the ICN are described first, followed by the horticultural contributions to naming artificial hybrids under the ICNCP. The two codes have different spheres of responsibility, but these spheres may intersect and overlap, and the resulting interactions have implications for our interpretation of nomenclatural acts. The spheres of influence and division of responsibilities of each code, their respective requirements for publication of names, and the interaction between the two codes with respect to naturally occurring hybrids are discussed at the end of this review, following the summary histories provided for nomenclatural acts under each code.

The botanical naming history

Frederick Manson Bailey was the first to propose formal taxonomic recognition of the natural hybrid between *Dendrobium kingianum* and *D. speciosum* when he published the variety *Dendrobium speciosum* var. *delicatum* F.M.Bailey. From the very start, the nomenclatural history associated with the plants that I will call *Dendrobium* × *delicatum* (F.M.Bailey) F.M.Bailey throughout this article, in conformity with common usage, was fraught by misadventure.

Bailey had intended to publish *D. speciosum* var. *delicatum* in the first volume of the *Proceedings of the Royal Society of Queensland*, but the attention garnered by the fact that Queensland had a Royal Society was such that a detailed summary of the Society's first meeting was published in *The Brisbane Courier Mail* in the newspaper printed on the 1 September 1883. The account of Dr Bailey's talk to the Society's inaugural meeting (Anonymous 1883) was sufficiently detailed that it fulfilled the requirements for effective and valid publication under the *International Code of Nomenclature* (Turland et al. 2018). Bailey (1884) was understandably embarrassed by this situation, even though it is by no means unique among Australian orchids, *Dendrobium fairfaxii* F.Muell. & Fitzg. had earlier been published in *The Sydney Mail and New South Wales Advertiser* in 1872. Bailey's epithet *delicatum* referred to the labellum, which was 'of a very delicate texture, white speckled with purple, the middle lobe apiculate' (Bailey 1884: 11), features that in most cases distinguish *D.* × *delicatum* from both parents. The plants described by Bailey were gathered by Benjamin Crow and Carl Hartmann on the 'Main Range' inland from Brisbane, at a locality thought to be Spring Bluff (Overall 1963). Wild collected plants from Spring Bluff are still widely cultivated (Figure 1).

Figure 1. Flowers of a naturally occurring *Dendrobium* × *delicatum* from Spring Bluff, Queensland, in cultivation. Plant cultivated and photographed by M. Renner.

Bailey (1902) elevated his variety to species rank in the fifth volume of the *Queensland Flora*, there accepting the taxon as a species, rather than as having a hybrid origin.

Until the late 1920's, natural occurrences of *D.* × *delicatum* were associated with ranges in south-eastern Queensland, but in 1930, plants distinct from, but growing with, *D. kingianum* and *D. speciosum* at Alum Mountain, near Bulahdelah were sent to Herman Montague Rucker Rupp by Kesteven. Rupp (1931) described these plants from Alum Mountain as *Dendrobium kestevenii* Rupp. and noted the plants' affinities to both *D. speciosum* and *D. kingianum*, and also postulated a possible a hybrid origin for his "species".

Rupp (1944) described in *D. kestevenii* a new variety, *D. kestevenii* var. *coloratum* Rupp, based on a plant cultivated at Bulahdelah, so reaffirming his view that *D. delicatum* and *D. kestevenii* warranted recognition as separate species.

However, a hybrid origin for *D.* × *delicatum* was regarded as a near certainty by Rupp and Hunt (1948), who were 'practically certain that the origin of *D. delicatum* lies in natural hybridization between *D. speciosum* and *D. kingianum*'. Rupp and Hunt (1948) present Australian botanists as previously skeptical of evidence from experimental crossings of *D. speciosum* and *D. kingianum* in England, suspecting that English botanists were confusing the white-flowering form of *D. kingianum* with *D. delicatum*. There are grounds for this concern, given the *D. kingianum* var. *album* described and illustrated by Williams (1888) was a plant having inflorescences a foot long, and bearing 20 flowers whose segments were longer and narrower than in *D. kingianum*. *Dendrobium kingianum* has at most 15 flowers per raceme (Adams et al. 2021), and broadly triangular lateral sepals whose ventral margin is not, or scarcely inclined below the horizontal, such that the tips of the lateral sepals, the labellum midlobe, and the base of the mentum are arranged more or less at the same level across the bottom of the flower when viewed from the front. The illustration of *D. kingianum* var. *album* B.S.Williams presented by Williams (1888) shows a plant whose lateral sepals are triangular-falcate, and whose apices extend well below the tip of the labellum and mentum when viewed from the front, in a manner consistent with *D.* × *delicatum* due to the influence on flower shape coming from *D. speciosum*. The flower shape and flower count per inflorescence of *D. kingianum* var. *album* are more compatible with *D.* × *delicatum,* this view of its affinities was held by Dockrill (1993) and Adams and Lawson (1995) and is confirmed here. The illustration is the only known extant element of original material of *D. kingianum* var. *album* and is therefore designated as the lectotype of this variety below (ICN Art 9.3, 9.4). Experimental crosses between the putative parents were repeated in Australia by Dr H.E. Young of Brisbane (Rupp and Hunt 1948), the resulting plants being indistinguishable from natural *D.* × *delicatum,* and the matter was more or less settled. Rupp and Hunt (1948) also begrudgingly conceded that *D. delicatum* and *D. kestevenii* likely had the same hybrid parentage.

Debate about the status of these two taxa continued into the 1960's, when a consensus view emerged that both taxa represented sporadic hybrids between *D. kingianum* and two varieties of *D. speciosum*, *D. speciosum* var. *hillii* Mast. in the case of *D. delicatum* and *D. speciosum* var. *speciosum* in the case of *D. kestevenii* (Blombery 1965; Kirkland 1967; Overall 1963, 1969; Clemesha 1970).

That consensus view endured for nearly two decades, until a proposal to elevate the varieties then recognised within *Dendrobium speciosum* to species rank was published by Clements (1989). Recognition of *Dendrobium speciosum* var. *hillii* as *Dendrobium tarberi* M.A.Clem. created an opening for the recognition of both *D.* × *delicatum* and *D.* × *kestevenii* because under the concepts of Clements (1989), the two entities then represented progeny from hybridisation events involving two different sets of parental species. However, despite the persistence of proposals to recognise the myriad of morphotypes within *Dendrobium speciosum* as distinct species (e.g. Jones 2021), empirical data from both morphological and molecular sources gathered to date support a broad circumscription for *D. speciosum*, reflecting the clinal pattern of morphological variation across this geographic distribution (Adams et al. 2006), and patterns of genetic substructure and admixture (Simpson et al. 2018). This justifiably broad circumscription of *D. speciosum* condemns *D.* × *kestevenii* to synonymy of *D.* × *delicatum*. Or so we thought, because there seems to be an embedded nomenclatural issue arising when we consider horticultural contributions to nomenclature, as have been raised by Shaw (2014), among others.

The horticultural naming history

The first flowering of an artificial hybrid between *Dendrobium kingianum* and *D. speciosum* was announced in The *Gardners' Chronicle*, a weekly periodical, published on 26 March 1892, wherein it was stated that 'Sir Trevor Lawrence, Bart. MP., Barford Lodge, staged plants of *Dendrobium speciosum* (pod) × *D. kingianum*, which had small white flowers' (Anonymous 1892). Though the hybrid combination was stated, no name was proposed for the hybrid plants in this article. The absence of a name for the grex means that no grex name was proposed, and none was established in this publication (ICNCP Art. 27.3 was fulfilled, but Art. 27.1 and Art. 23.1 were not).

Four years later, Lawrence's hybrid received an Award of Merit from the Royal Horticultural Society, which garnered mention in several articles published in 1896. The first of these was in The *Gardners' Chronicle* of 12 March 1896, where the name *Dendrobium* specio-Kingianum was used for the hybrid, but no statement of the hybrid combination was provided (Anonymous 1896a). The grex name was therefore not formally established in this article either.

On 14 March 1896, *Dendrobium* specio-Kingianum was mentioned in *The Garden* (Anonymous 1896c), with a brief description of inflorescence habit and flower colour, but no statement of parentage. The lack of a statement of the hybrid's parentage in this article, in terms of the hybrid combination, meant the requirements for establishment under the ICNCP were not fulfilled.

However, the form of the name, and its publication with a description of the plant, albeit a brief description, at face value appears to have inadvertently fulfilled the requirements of the ICN for the valid publication of a species name, a point to which we will return.

The next mention of the hybrid was in *The Orchid Review* Volume IV, No. 40, dated April 1896, on page 107, where, under 'The Hybridist' segment *Dendrobium* × *Kingiano-speciosum* was given as the hybrid's name, and the parents stated as being '*D. speciosum* (pod) and *D. kingianum* (pollen), of which a good plant was exhibited at the Royal Horticultural Societies meeting on March 10th last' (Anonymous 1896b). The provision of a name for the grex, and the statement of the hybrid combination, fulfils the requirements for establishment of the grex name *D.* Kingiano-speciosum for this hybrid. It seems that this was the first time the requirements for establishment of a grex were fulfilled. The exact date of publication of *The Orchid Review* Volume IV No. 40 is not stated, but *The Orchid Review* was a self-described 'Illustrated Monthly Journal' whose April 1896 issue opens with notes stating 'Two meetings of the Royal Horticultural Society will be held during April, on the 7th and 21st respectively, when the Orchid Committee will meet at the usual hour of 12 o'clock, noon'. From this we can conclude that the April volume was published and distributed to subscribers in sufficient time for that information to be of use, most probably at the end of March or early in April.

The next mention of Lawrence's hybrid was in the *Journal of the Royal Horticultural Society* Volume XX of 1896–97, in the Extracts from the Proceedings of the Royal Horticultural Society (Anonymous 1896d), where the granting of an Award of Merit to '*Dendrobium* × *Specio-Kingianum* (*D. speciosum* × *D. kingianum*) (votes unanimous), from Sir Trevor Lawrence, Bart. Burford, Dorking (gr. Mr. W.H. White)' was reported. The statement of a grex name and the hybrid combination fulfil the requirements for establishing the grex name. The date of publication of Volume XX is not stated, but the volume includes a report on the Temple Show held on 19, 20 and 21 May 1896. Also recorded are attendance and topic of talk for the general meeting held on 23 June 1896, minutes from the meeting of the Scientific Committee on the same date, and awards recommended by the Fruit and Vegetable Committee at Chiswick on 29 June 1896. These were all included in the extracts from the Proceedings of the Royal Horticultural Society in a sequentially numbered appendix whose meetings and shows are not chronologically arranged. On this evidence it is reasonable to conclude that Volume XX was published as single product, and it was published in the second half of 1896. This is the first time the requirements for establishment of the grex name *D.* Specio-kingianum were met, and the evidence suggests the establishment of that name post-dates the establishment of *D.* Kingiano-speciosum.

Thirteen years later, another name was proposed for Lawrence's hybrid, when *Dendrobium* × *spyersii* was listed in *The Orchid Stud-book* (Rolfe and Hurst 1909: 12, 13, 81) as the name for progeny of the crossing between *D. kingianum* and *D. speciosum*. Rolfe and Hurst (1909) seem to have been the first to publish the name *Dendrobium* × *spyersii* for the hybrid, even though they attributed the name to Lawrence in a publication of 1892. It is possible they refer to the first published mention of the hybrid, being the notice of first flowering published in *The Gardners' Chronicle* (Anonymous 1892), but only the hybrid combination was published there, and no grex name was proposed. Missing from the list of synonyms of *D.* × *spyersii* is D. Specio-Kingianum, *J. Roy. Hort. Soc. London* XX: ciii–civ (1896).

The next relevant mention in horticultural literature was eight decades later, when the *Handbook of Orchid Nomenclature and Registration* (1993) took the view that *D. speciokingianum* had been validly published and had priority over *D.* × *delicatum* as the name for both nothospecies and hybrid. Shaw (2014) also emphasized priority of the name *D. speciokingianum* in a nomenclatural note in the *Quarterly Supplement to the International Register and Checklist of orchid hybrids*. Shaw (2014) argued *Dendrobium speciokingianum* was the earliest available name at species rank for the naturally occurring hybrid between *D. kingianum* and *D. speciosum*, even though it is not the earliest published name. Because names only have priority in the rank at which they were proposed or combined, at varietal rank *D. speciosum* var. *delicatum* has priority, but at species rank *D. speciokingianum* has priority.

Capell (2024) took Shaw's (2014) interpretation a step further, asserting that not only was *D.* × *speciokingianum* the correct name for the natural hybrid, it was also, as *D.* Speciokingianum, the correct name for the artificial hybrid. These assertions have not been satisfactorily addressed.

Discussion

At face value, there appears to be some merit to arguments made in favour of accepting *D. speciokingianum* as the correct name for *D.* × *delicatum* in terms of its earlier publication date at species rank, given that the requirements for effective and valid, if inadvertent, publication appear to have been fulfilled in 1896, in *The Garden* (Anonymous 1896c). At that time, it was permissible for descriptions to be in English, and there was no requirement to designate a type specimen, or even indicate a country of origin. In *The Gardners' Chronicle*, *Dendrobium specio-Kingianum* was published with a species name combining the epithets of the two parents in hyphenated form, with the termination of the *Kingianum* epithet unaltered. The named plant was known to be a hybrid, as avowed in the combination of the two parental epithets to form the hybrid's name. Constructions of this form, however, are considered to be formulae rather than epithets, as defined by the ICN Article H.10.2. The ICN provides guidance on the interpretation of Art. H.10.2 in Example 3, the case of *Verbascum nigro-lychnitis* (Schiede, *Pl. Hybr.*: 40, 1825), which is considered to be a formula meaning the correct binary name for the hybrid between *V. lychnitis* L. and *V. nigrum* L.; is *V.* × *schiedeanum* W.D.J.Koch (*Syn. Fl. Germ. Helv.*, ed. 2: 592, 1844). *Dendrobium specio-Kingianum* shares with *V. nigro-lychnitis* the formulaic construction based on the two parental epithets, one of which is unaltered, meaning the correct interpretation of *D. specio-Kingianum* is, like *V. nigro-lychnitis*, that it is not an epithet, and therefore is not a published name, and can be neither valid nor invalid as such. Because it is not a published name, it cannot exert priority at species rank over names subsequently published at that rank. The argument that *Dendrobium specio-Kingianum* was inadvertently proposed for a *species*, rather than a *nothospecies* (a plant of hybrid origin), has little merit. Knowledge of the plant's hybrid origin is avowed in the name proposed for the plant. The other publications including this hybrid also used a name derived from the epithets of the two parents combined with a hyphen, either *D.* Kingiano-speciosum or *D.* Specio-kingianum, and in all cases these publications failed to establish *epithets* for the nothospecies. The absence of the name *D.* × *speciokingianum* from Clements' (1989) *Checklist of*

Australian Orchids can then be explained by the fact that it is no name at all. Assertions that *D.* × *speciokingianum*, or any other name that is defined as a formula under the ICN, are the earliest validly published name for the nothospecies *D.* × *delicatum* are therefore incorrect.

The earliest validly published name for the nothospecies at species rank is *Dendrobium* × *delicatum* (as *D. delicatum* when published in 1902), because names can be moved between the species and nothospecies categories without changing date of publication or authorship (ICN Art. 50.1).

The nothovariety *D.* × *speciokingianum* var. *delicatum* (F.M.Bailey) R.Govaerts & J.M.H. Shaw (Shaw 2014 p. 36) is invalid, because the species name is not available for the formation of infraspecific taxa (Art. 35.1). Regardless of this invalidity, the variety of *D. speciosum* used as the parent of Lawrence's hybrid remains an open question, as does the identity of the so-called *D. kingianum* used which, if *D. kingianum var. album* was used, may have been a *D.* × *delicatum*.

There has also been confusion surrounding the establishment of the grex name for the hybrid between *D. speciosum* and *D. kingianum* when raised artificially. Capell (2024) stated that it was clear the name for the grex resulting the cross of *D. kingianum* and *D. speciosum* was *D.* Specio-kingianum. However, when the grex names of hybrids are in Latin form, the ICNCP seems to defer governance of the form of those names to the ICN (ICNCP Principle 2). This means that the same Art. H.10.2 could then apply to all the intended grex names based on a hyphenated combination of the parental species epithets. If these are then to be regarded as formulae, not names, the earliest grex name for the artificial hybrid established in accordance with the ICNCP and ICN in Latin form appears to be *Dendrobium* × *spyersii*, published in *The Orchid Stud-book* (Rolfe and Hurst 1909). If we accept that other grex names proposed based on Latinised species names are not of Latin form and are then permissible because they do not fall under the orthographic jurisdiction of the ICN, then the earliest established grex name appears to be *D.* Kingiano-speciosum. However, whether such names are acceptable as non-Latinised is unclear, and this is not an issue pursued further here.

Neither of these candidate grex names have been applied to cultivated plants of horticultural origin, which have been consistently referred to as *Dendrobium* Delicatum or *D.* × *delicatum* since the 1960's, when the issues surrounding hybrid origin, circumscription, and priority among competing names was resolved. A grex may share with a nothospecies the nothospecies' epithet when they have the same parentage, the grex name being distinguished by having an upper case first letter, and regular font, not italics. The relevant note of the ICNCP uses the word 'established', meaning that to be established as a grex name, the nothospecies epithet must be restated in conjunction with the names of both parents, if this was not done when the nothospecies was published. Registration is not a requirement of grex name establishment, rather it is a mechanism to avoid proposing the same name for a different grex.

This is not the first time that issues of priority have arisen in the naming of one of Australia's naturally occurring hybrid *Dendrobium* (or more precisely, in the application of names). An earlier name, *Dendrobium* × *nitidum,* was recently found for the plant we know as *Dendrobium* × *gracillimum*. The *International Code of Nomenclature* has *priority* of names as a guiding principle, but also has mechanisms to avoid replacing well-established names simply because an earlier name is found, promoting the *stability* of names. Even if an earlier name for *Dendrobium* × *delicatum* existed, there would be considerable merit in conserving this well-established and long-used name for this familiar and horticulturally significant hybrid, just as there was for *D.* × *gracillimum* (Renner 2020). However, *D.* × *delicatum* is the earliest validly published nothospecies name, and conservation against an earlier name is not required. Similar conservation mechanisms exist under the ICNCP (Art. 11.7) and could be applied in the case of *D.* Delicatum against *D.* × *spyersii* or *D.* Kingiano-speciosum (if the latter is acceptable as a name). There seems little to be gained by having two names in Latin form for the same hybrid, when differences in origin can be reflected by typographical modification of the nothospecies epithet, as is current established practice.

Taxonomic Treatment

Dendrobium* × *delicatum (F.M.Bailey) F.M.Bailey, *The Queensland Flora* 5: 1527 (1902).

Basionym: *Dendrobium speciosum* var. *delicatum* F.M.Bailey, *The Brisbane Courier* 38(8000): 10 (1883).

≡ *Tropilis* × *delicata* (F.M.Bailey) Butzin, *Willdenowia* 12: 251 (1982).

≡ *Thelychiton* × *delicatus* (F.M.Bailey) M.A.Clem. & D.L.Jones, *The Orchadian* 13: 491 (2002).

≡ *Dendrobium* × *speciokingianum* nothovar. *delicatum* (F.M.Bailey) R.Govaerts & J.M.H.Shaw, *The Orchid Review* 122: 36 (2014), *nom. inval.* (ICN Art. 35.1).

Original material: 'Main Range. Collected by B. Crow and C.H. Hartmann'.

= *Dendrobium kingianum* var. *album* B.S.Williams, *The Orchid Album* 7: 322 (1888).

Original material: 'Native of Australia.... For the opportunity of figuring this rare plant we are indebted to A.H. Smee Esq., The Grange, Carabalton, in whose well-known collection the plant bloomed in the early part of the present year'.

Lectotype (here designated) [illustration]: *The Orchid Album* 7: Plate 332.

= *Dendrobium* × *spyersii* Lawrence ex Rolfe and Hurst, *The Orchid Stud-book* 81 (1909), *nom. inval.* (ICN Art. 38.1).

Original material: not stated.

= *Dendrobium* × *delicatum* var. *kestevenii* (Rupp) Leaney, *Australian Plants* 1: 19 (1960).

= *Dendrobium* × *kestevenii* Rupp, *Proceedings of the Linnean Society of New South Wales* 56(2): 137 (1931).

Original material: 'This very beautiful orchid was set to me in September, 1930, by Dr. H.L. Kesteven of Bullahdelah, whose sons had discovered it on the rocks of the easter side of the Alum Mountain.'

= *Dendrobium kestevenii* var. *coloratum* Rupp, *The Orchids of New South Wales* 144 (1944).

Original material: 'Northbridge (cult. from plant originally from Bullahdelah, Fieldsend, 9.1936), 1943, Rupp 9'.

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References

Adams PB, Lawson SD (1995) Dendrobium kingianum. *A unique Australian orchid*. (Central Queensland University Press: Rockhampton Queensland)

Adams PB, Burke JM, Lawson SD (2006). A review of the taxonomy and relationships of the *Dendrobium speciosum* complex (Orchidaceae), and recognition of two new taxa. *Telopea* 11: 195–232. DOI

Adams PB, Lawson SD, Renner MAM (2021) A review of *Dendrobium kingianum* Bidwill ex Lindl. (Orchidaceae) with morphological and molecular-phylogenetic analyses. *Telopea* 24: 203–232. DOI

Anonymous (1883) Mr. Bailey's Paper, in Queensland Philosophical Society. *The Brisbane Courier* 38(8000): 10. URL

Anonymous (1892) *The Gardners' Chronicle* Series 3. 11. URL

Anonymous (1896a) Societies. Royal Horticultural. *The Gardners' Chronicle* Series 3. 19, 337–338. URL

Anonymous (1896b) The Hybridist. *The Orchid Review* 4: 107–109. URL

Anonymous (1896c) Societies and Exhibitions. *The Garden: an illustrated weekly journal of gardening in all its branches* 49: 201–203. URL

Anonymous (1896d) Orchid committee, March 10, 1896. *Journal of the Royal Horticultural Society of London* 20: ci–cv. URL

Bailey FM (1884) Contributions to the Queensland flora. *The Proceedings of the Royal Society of Queensland* 1: 8–17. URL

Bailey FM (1902) *The Queensland Flora* 5: 1373–1700. (Government Printer: Brisbane) URL

Blombery AM (1965) *Dendrobium delicatum* (F.M.Bail.) F.M.Bail. *The Orchadian* 2: 10–11.

Brickell CD, Alexander C, Cubey JJ, David JC, Hoffman MHA, Leslie AC, Malécot V, Jin X (2016) International Code of Nomenclature for Cultivated Plants. Ninth Edition. *Scripta Horticulturae* 18: 1–180. PDF

Capell R (2024) Comments on recent ANOS awards. *The Orchadian* 21: 116–128.

Clements MA (1989) Catalogue of Australian Orchidaceae. *Australian Orchid Research* 1: 62. PDF

Clemesha S (1970) *Dendrobium kingianum* Bidw. *The Orchadian* 3: 86–87.

Dockrill AW (1993), *Australian indigenous orchids*. *The epiphytes, the tropical terrestrial species*. Edition 2, Volume 1. (Surrey Beatty & Sons: Frenchs Forest)

Jones DL (2021) *A complete guide to native orchids of Australia*. Edition 3. (New Holland Publishers: Sydney)

Kirkland K (1967) The orchids of Australia. *The Orchadian* 2: 78–81.

Overall HJR (1963) *Dendrobium kingianum* Bidw. *The Orchadian* 2: 14–15. URL

Overall HJR (1969) The lure of the orchid. *The Orchadian* 3: 58–59.

Renner MAM (2020) (2771) Proposal to conserve *Dendrobium* × *gracillimum* against *D.* × *nitidum* (Orchidaceae). *Taxon* 69: 1113–1114. DOI

Rolfe RA, Hurst CC (1909) *The orchid stud-book*. (Frank Leslie & Co: London) URL

Rupp HMR (1931) Further notes on the orchids of the south Maitland coalfields, with description of a new *Dendrobium* from Bullahdelah. *Proceedings of the Linnean Society of New South Wales* 56(2): 133–138. URL

Rupp HMR (1943) *The orchids of New South Wales*. *(Australasian Medical Publishing: Sydney)*

Rupp, HMR, Hunt TE (1948) *A review of the genus Dendrobium* (Orchidaceae) in Australia. *Proceedings of the Linnean Society of New South Wales* 72: 233–251.

Shaw JMH (2014) Quarterly supplement to the international register and checklist of orchid hybrids (Sander's list). January–March 2014 registrations. *The Orchid Review* 122: 21–40.

Simpson L, Clements MA, Crayn DM, Nargar K (2018) Evolution in Australia's mesic biome under past and future climates: insights from a phylogenetic study of the Australian rock orchids (*Dendrobium speciosum* complex, Orchidaceae). *Molecular Phylogenetics and Evolution* 218: 32–46. DOI

Turland NJ, Wiersema JH, Barrie FR, Greuter W, Hawksworth DL, Herendeen PS, Knapp S, Kusber W-H, Li D-Z, Marhold K, May TW, Monro AM, Prado J, Price MJ, Smith GF (eds) (2018). International Code of Nomenclature for algae, fungi, and plants (Shenzhen Code) adopted by the Nineteenth International Botanical Congress Shenzhen, China, July 2017. *Regnum Vegetabile* 159. (Glashütten: Koeltz Botanical Books) DOI

Williams BS (1888) *Dendrobium kingianum album*. *The Orchid Album* 7: t. 332. URL

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A checklist of the hornwort and liverwort flora of the Kermadec Islands, New Zealand Botanical Region

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Abstract

We accept 134 taxa at species rank and below belonging to 25 families as present on the Kermadec Islands, three times the number previously reported. One liverwort, *Lunularia cruciata* is regarded as introduced to the islands. More than half the indigenous species of the Kermadec Islands belong to just three families, Lejeuneaceae, Lepidoziaceae and Lophocoleaceae, which are together represented by 71 species. All but 16 of the hornwort and liverwort taxa that occur on the Kermadec Islands also occur in New Zealand, reflecting strong links to the New Zealand flora via long-distance dispersal.

Introduction

The Kermadec Islands Group (29°15′–31°30′S, 177°55′–179°W) (Fig. 1) is the northernmost extension of the New Zealand Botanical Region (*sensu* Allan 1961; Wardle 1991, but see comments by Trnski & de Lange 2015). The Kermadec Islands (Fig. 1) are mostly andesitic volcanic islands resulting from ongoing subduction between the overriding Indo-Australian Plate and the subducted Pacific Plate (Lloyd & Nathan 1981). The Group comprises three main islands, and several smaller islands and isolated rocks, the largest islands are (from North to South): Raoul Island (2943 ha, c.520 m a.s.l.), Macauley Island (323.75 ha, 238 m. a.s.l.) and Curtis Island (52.6 ha, 137 m a.s.l.) (data from Sykes 1977). Raoul (Fig. 2) is a volcanically active, cliff-girt, heavily forested island whose canopy is dominated by *Metrosideros kermadecensis* W.R.B.Oliv., while Macauley (Fig. 3), also cliff-girt, is currently volcanically quiescent, though often beset by earthquakes. Macauley is mostly vegetated by a dense fernland of *Hypolepis dicksonioides* (Endl.) Hook. (de Lange 2015a). Curtis (Fig. 4) is volcanically active and is mostly vegetated by a low turf of Kermadec ice plant (*Disphyma australe* subsp. *stricticaule* Chinnock). Climate data is available only for Raoul Island, where a meteorological station is maintained by the New Zealand Department of Conservation (DOC). The climate of Raoul Island is humid, subtropical, (data from https://en.wikipedia.org/wiki/Raoul_Island#Climate accessed 19 March 2018), and warm and wet throughout the year, though winter is slightly wetter, with a mean annual precipitation of 1558 mm. Diurnal temperatures (gathered since the 1940s) range from an average high of 22.1°C to an average low of 16.7°C. In the summer months temperatures reach an average daytime maximum of 25.7°C and minimum of 20.5°C, and in winter temperatures may drop to lows of 13.3°C. All of the islands are subjected to infrequent, high intensity tropical cyclones (Morton 1957; Sykes 1977; Revell 1981; Terry 2007; de Lange & Galloway 2015), that have a major impact on island vegetation.

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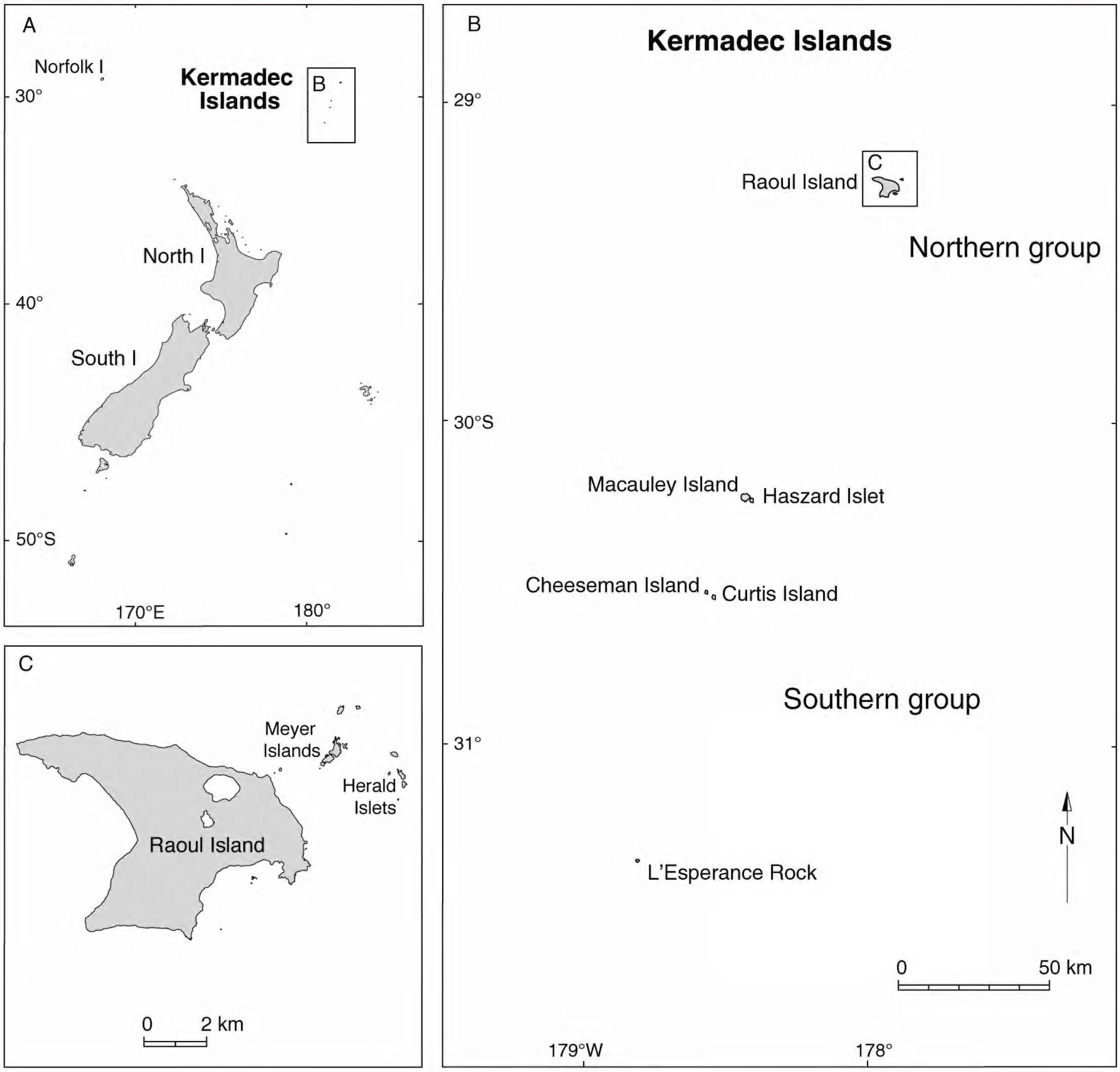

Figure 1. The Kermadec Islands. A. Location of the Kermadec Islands in relation to New Zealand. B. The Kermadec Islands chain, showing the northern group (C – see inset) and southern group, C. Northern group showing Raoul Island, The Meyer Islands and Herald Islets.

The vascular flora of the Kermadec Island Group has been well documented (Sykes 1977; Sykes & West 1996), and there are now 22 formally described plant taxa endemic to the Kermadecs, all at species level or below (Sykes 1977; de Lange et al. 2005; Wilmot-Dear & Friis 2006; Perrie & Brownsey 2012; de Lange et al. 2013; Cameron & Sykes 2015). There are no endemic vascular plant genera and all of the endemic vascular plant species are closely related to taxa on the nearest islands, especially New Zealand to the south west (see Sykes 1977; de Lange et al. 2005; Wimot-Dear & Friis 2006; de Lange et al. 2013).

In contrast to the vascular flora, however, the bryophyte flora, including hornworts, liverworts and mosses, has been poorly documented (de Lange & Beever 2015). Over the last two decades the Kermadec Islands moss flora has been carefully scrutinized and published (Beever et al. 1996; de Lange & Beever 2015) but documentation of the hornwort and liverwort flora, the focus of this paper, has scarcely advanced from the preliminary checklist prepared by Ella Campbell and published in Sykes (1977). Campbell's list, based in large part on collections made by Sykes from Raoul and Macauley Islands, reported 20 hornwort and liverwort taxa. Since then there have been several contributions adding species to the Kermadec Islands liverwort and hornwort flora including new records (Campbell 1997; Renner & de Lange 2011; Renner et al. 2013a; Braggins et al. 2014; Renner 2018), descriptions of two supposedly new and endemic taxa (Engel & Merrill 1999; Renner 2005), and reinstatements of previously synonymized taxa (So 2001; Engel & Merrill 2010). However, with few exceptions, these Kermadec reports have been included as part of wider-reaching generic monographs and there is still no single comprehensive listing for all of the hornworts and liverworts of the Kermadec Islands Group. Two liverworts were once thought endemic to the Kermadec Islands, however,

Plagiochila pacifica Mitt. has been found on Rarotonga in the Cook Islands Group (Renner 2018) and *Radula cordiloba* subsp. *erigens* M.A.M.Renner et Braggins is now treated as a synonym of a broadly circumscribed *R. javanica* Gottsche, Lindenb. et Nees (Renner 2014). With these changes, there are now no bryophytes regarded as endemic to the Kermadec Islands.

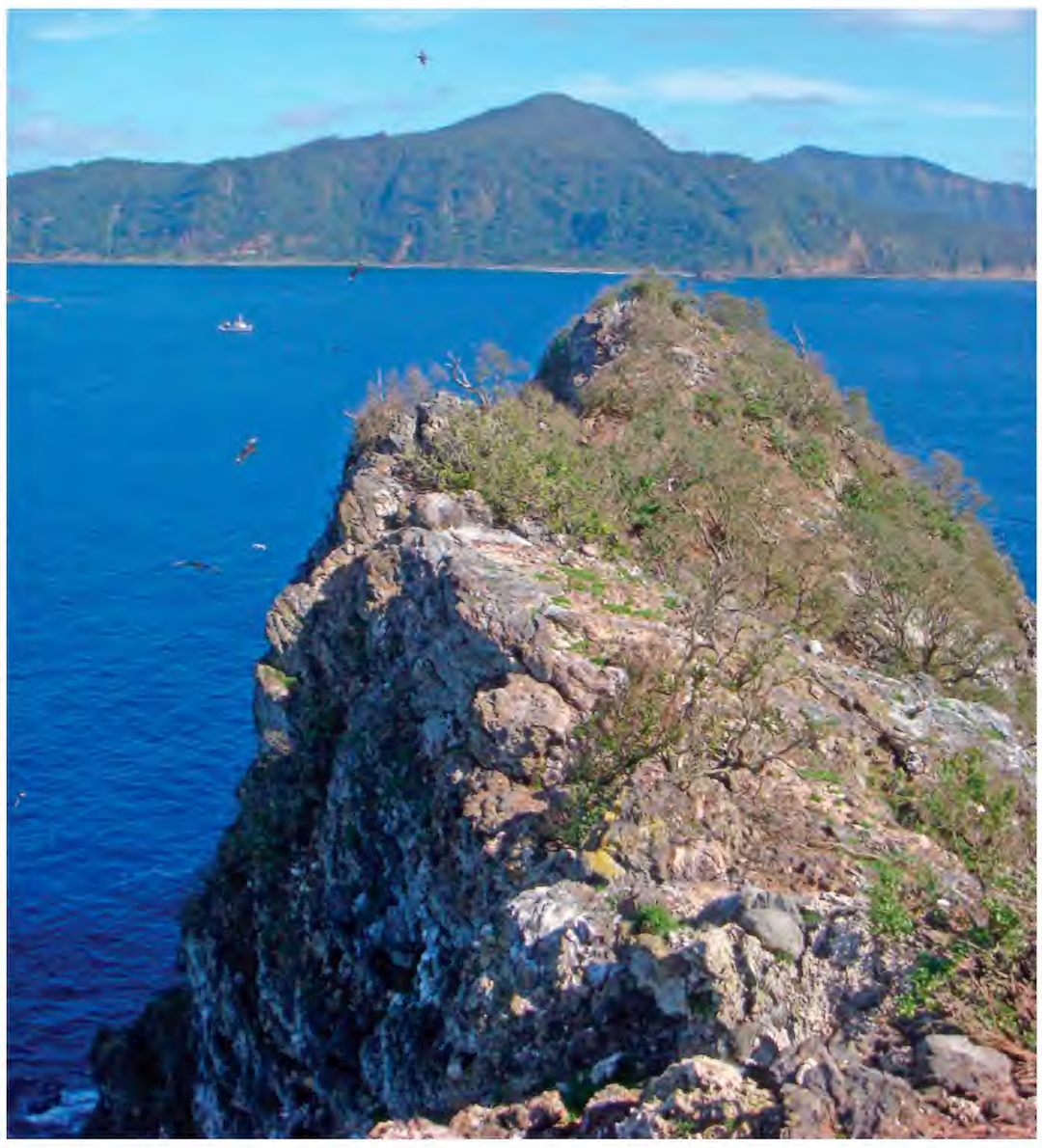

Figure 2. The northern side of Raoul Island as viewed from Napier Island (image: Peter J. de Lange).

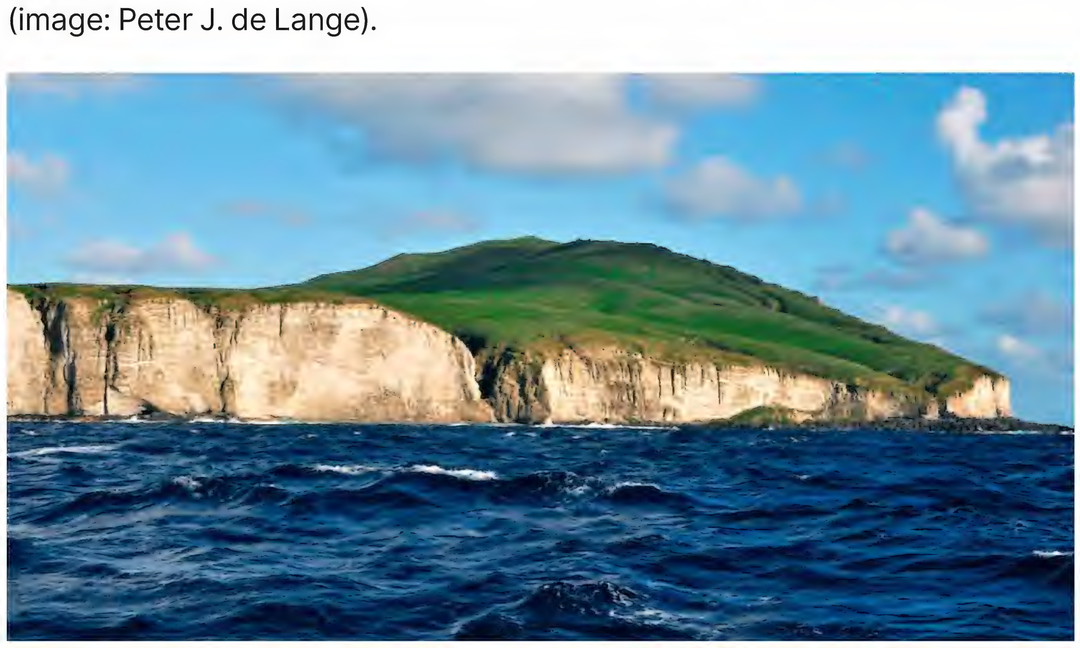

Figure 3. The northern coastline of Macauley Island (image: Malcolm Francis).

Figure 4. Curtis Island as viewed from Cheeseman Island (image: Warren Chinn).

Methods

In May 2009, and May 2011 the senior author (P. J. de Lange, hereafter PdL) undertook field work within the Kermadec Islands. During May 2009 under the auspices of the New Zealand Department of Conservation (hereafter DOC) PdL spent two full days on Raoul Island (Renner & de Lange 2011). The May 2011 visit, conducted as a participant of the Kermadec Biodiscovery Expedition (Trnski & de Lange 2015), was more comprehensive, with landings made by PdL on all the main islands, islets and rock stacks except for Curtis, Haszard, "Haszardette", Milne and the Dougal Rocks (see de Lange 2011a,b,c; de Lange 2012).

As a result of visits in 2009 and 2011 477 packets of hornworts and liverworts were collected. Vouchers are lodged in AK with duplicates in CHR, F, NSW and WELT (herbarium accronyms follow Thiers (2018)). We present a revised checklist of the hornworts and liverworts of the Kermadec Islands based on these collections and supplemented by studies of Kermadec specimens held in other herbaria and literature records. This reflects a more complete knowledge of the hornwort and liverwort flora facilitating comparisons with other island flora in the South Pacific.

Results

In total, 122 formally described and accepted taxa, and 12 taxa that are either potentially new to science or require further critical study are now known for the Kermadec Islands Group (Table 1). Hornwort and liverwort nomenclature follows Söderstrom et al. (2016) and subsequent updates. Authorities for hornworts and liverworts are given in the checklist (see Table 1); those of other plants within the main body of the text. For each record a single representative voucher is cited. Voucher specimens for this list are those that have been personally examined by the authors from collections held in AK (including AKU), F, CHR, MPN, NSW, and WELT including specimens that had been previously examined by E.O. Campbell (Campbell in Sykes 1997; Campbell 1997) and which we have been able to locate. The distribution of hornworts and liverworts within the Kermadec Islands Group is summarised in Table 2.

Discussion

This paper builds on the knowledge of the hornwort and liverwort flora of the Kermadec Islands presented by Campbell in Sykes (1977) and subsequent literature (see introduction). We accept 134 taxa at species rank and below belonging to 25 families as present on the Kermadec Islands, three times the number previously reported. This is perhaps unsurprising, given virtually all past scientific expeditions to these islands have concentrated on the macrofauna (birds especially), and vascular plants (see summary in Gentry 2013).

One liverwort, *Lunularia cruciata* is regarded as probably introduced to the islands, reflecting perhaps on the assumption the source of introduction came from New Zealand (de Lange 2015a).

Table 1. Liverworts and hornworts of the Kermadec Islands, with representative voucher specimens, a generalised distribution that describes species occurrence in the surrounding segment of the globe south of the equator, and whether or not the species occurs on mainland New Zealand. In the table NZ=New Zealand, PNG=Papua New Guinea.

Species	Family	Voucher	Generalised distribution	Mainland NZ occurrence
Acrobolbus knightii (Mitt.) Briscoe	Acrobolbaceae	AK 305070	NZ endemic	Y
Acrolejeunea mollis (Hook.f. & Taylor) Schffin.	Lejeuneaceae	AK 313888	NZ endemic	Y
Acrolejeunea pycnoclada (Taylor) Schiffn. subsp. *pycnoclada*	Lejeuneaceae	AK 325478	Australasian and PNG	N
Acrolejeunea securifolia (Endl.) Steph. subsp. *securifolia*	Lejeuneaceae	AK 305090	Malesia-Pacific-Australasia	Y
Allisoniella recurva R.M.Schust.	Cephaloziellaceae	AK 305311	NZ endemic	Y
Anthoceros sp.	Anthocerotaceae	AK 313858		
Asterella australis (Hook.f. & Taylor) Verd.	Aytoniaceae	AK 325532	Australasian temperate	Y
Balantiopsis diplophylla (Hook.f. & Taylor) Mitt. var. *diplophylla*	Balantiopsaceae	AK 305273	Australasian temperate	Y
Bazzania adnexa (Lehm. & Lindenb.) Trevis.	Lepidoziaceae	AK 305277	Australasian temperate	Y
Bazzania novae-zelandiae (Mitt.) Besch. & C.Massal.	Lepidoziaceae	AK 305215	Australasian temperate	Y
Bazzania tayloriana (Mitt.) Kuntze	Lepidoziaceae	AK 305292	NZ endemic	Y
Ceramanus perfragilis (J.J.Engel & G.L.Merr.) E.D.Cooper	Lepidoziaceae	AK 305304	NZ endemic	Y
Ceratolejeunea belangeriana (Gottsche) Steph.	Lejeuneaceae	AK 329755	Malesia-Pacific-Australasia	N
Cheilolejeunea ceylanica (Gottsche) R.M.Schust. & Kachroo	Lejeuneaceae	AK 325644 p.p.	Malesia-Pacific-Australasia	N
Cheilolejeunea mimosa (Hook.f. & Taylor) R.M.Schust.	Lejeuneaceae	CHR161835	Australasian temperate	Y
Cheilolejeunea parvidens	Lejeuneaceae	AK313943	Australasian temperate	Y
Cheilolejeunea trifaria (Reinw., Blume & Nees) Mizut.	Lejeuneaceae	AK 305163	Malesia-Pacific-Australasia	N
Cheilolejeunea sp. (a)	Lejeuneaceae	AK 287598		
Cheilolejeunea sp. (k)	Lejeuneaceae	AK 313683		
Chiloscyphus excisifolius (Steph.) J.J.Engel & R.M.Schust.	Lophocoleaceae		Australasian temperate	N
Chiloscyphus lentus (Hook.f. & Taylor) J.J.Engel & R.M.Schust.	Lophocoleaceae	AK 305417	NZ endemic	Y
Chiloscyphus rupicola (Steph.) J.J.Engel & R.M.Schust.	Lophocoleaceae	AK 305303	Australasian temperate	Y
Chiloscyphus semiteres (Lehm.) Lehm.	Lophocoleaceae	AK 305777	Australasian temperate	Y
Chiloscyphus subporosus (Mitt.) J.J.Engel & R.M.Schust. var. *subporosus*	Lophocoleaceae	AK 305212	Australasian temperate	Y
Chiloscyphus aff. *bispinosus*	Lophocoleaceae	AK 305211	Australasian temperate	Y
Chiloscyphus aff. *novaezeelandiae*	Lophocoleaceae	AK 305099	Australasian temperate	Y
Cololejeunea cucullifolia (Herzog) E.A.Hodgs.	Lejeuneaceae	AK 325250	NZ endemic	Y
Cryptolophocolea helmsiana (Steph.) L.Söderstr.	Lophocoleaceae	AK 305614	Australasian temperate	Y
Cryptolophocolea mittenianus (Colenso) L.Söderstr.	Lophocoleaceae	AK 305418	NZ endemic	Y
Cumulolejeunea ocellata (Herzog) R.L.Shu & L.Shu	Lejeuneaceae	AK 325257	Australasian temperate	Y
Cuspidatula monodon (Taylor ex Lehm.) Steph.	Jamesoniellaceae	AK305126	Australasian temperate	Y
Dendroceros granulatus Mitt.	Dendrocerotaceae	AK325479	NZ endemic	Y
Dendromastigophora flagellifera (Hook.) R.M.Schust.	Mastigophoraceae	AK 305075	NZ endemic	Y
Dinckleria fruticella (Hook.f. & Taylor) J.J.Engel & Heinrichs	Plagiochilaceae	AK 305074	NZ endemic	Y
Drepanolejeunea aucklandica Steph.	Lejeuneaceae	AK 305415 p.p.	Australasian temperate	Y
Drepanolejeunea vesiculosa Herzog subsp. *vesiculosa*	Lejeuneaceae	CHR 595553	Pacific	N
Drucella integristipula (Steph.) E.A.Hodgs.	Lepidoziaceae	AK 305294	Australasian temperate	Y
Dumortiera hirsuta (Sw.) Nees	Marchantiaceae	AK 325170	Malesia-Pacific-Australasia	Y
Echinolejeunea papillata (Mitt.) R.M.Schust.	Lejeuneaceae	AK 313717	NZ endemic	Y
Frullania apiculata (Reinw., Blume & Nees) Dumort.	Frullaniaceae	AK 306176	Malesia-Pacific-Australasia	N
Frullania falciloba Lehm.	Frullaniaceae	AK 305091	Australasian temperate	Y
Frullania fugax (Hook.f. & Taylor) Gottsche, Lindenb. & Nees	Frullaniaceae	AK 306175	Australasian temperate	Y
Frullania pentalpleura Taylor	Frullaniaceae	AK 305079	Australasian temperate	Y
Frullania spinifera Taylor	Frullaniaceae	AK 306177	Australasian temperate	Y

Species	Family	Voucher	Generalised distribution	Mainland NZ occurrence
Frullania aff. *spinifera*	Frullaniaceae	AK 305125		
Frullania aff. *rostellata*	Frullaniaceae	AK 305095		
Frullania aff. *rostrata*	Frullaniaceae	AK 305081		
Frullania aff. *squarrosula*	Frullaniaceae	AK 306174		
Frullania sp. subgenus *Microfrullania*	Frullaniaceae	AK 305101 p.p.		
Frullania sp. subgenus *Trachycolea*	Frullaniaceae	AK 305101 p.p.		
Heteroscyphus allodontus (Hook.f. & Taylor) J.J.Engel & R.M.Schust.	Lophocoleaceae	AK 305186	Australasian temperate	Y
Heteroscyphus ammophilus (Colenso) R.M.Schust. var. *ammophilus*	Lophocoleaceae	AK 313211 p.p.	Australasian temperate	Y
Heteroscyphus argutus (Reinw., Blume & Nees) Schiffn.	Lophocoleaceae	AK 313190	Malesia-Pacific-Australasia	Y
Heteroscyphus cuneistipulus (Steph.) Schffin.	Lophocoleaceae	AK 305607	NZ endemic	Y
Heteroscyphus coalitus (Hook.f.) Schiffn. var. *coalitus*	Lophocoleaceae	AK 305610	Malesia-Pacific-Australasia	Y
Heteroscyphus echinellus (Lindenb. & Gottsche (Lindenb. & Gottsche) J.J.Engel & He-Nygrén var. *echinellus*	Lophocoleaceae	AK 325473	Australasian temperate	Y
Heteroscyphus fissistipus var. *multispinus* (E.A.Hodgs. & Allison) J.J.Engel	Lophocoleaceae	AK 305771	NZ endemic	Y
Heteroscyphus lingulatus (Colenso) J.J.Engel & R.M.Schust.	Lophocoleaceae	AK 305283	NZ endemic	Y
Heteroscyphus supinus (Hook.f. & Taylor) R.M.Schust.	Lophocoleaceae	AK 305618	Australasian and PNG	Y
Heteroscyphus triacanthus (Hook.f. & Taylor) Schiffn. var. *triacanthus*	Lophocoleaceae	AK 305223	Australasian temperate	Y
Hymenophyton flabellatum (Labill.) Trevis.	Hymenophytaceae	AK 305127	Australasian temperate	Y
Isotachis lyallii Mitt.	Balantiopsaceae	AK 305605	NZ endemic	Y
Kurzia moniliformis J.J.Engel	Lepidoziaceae	AK 305308	NZ endemic	Y
Kurzia quinquespina J.J.Engel & G.L.Merr.	Lepidoziaceae	AK 305746	NZ endemic	Y
Lamellocolea granditexta (Steph.) J.J.Engel	Lophocoleaceae	AK 305619	NZ endemic	Y
Lejeunea anisophylla Mont.	Lejeuneaceae	AK 313203	Malesia-Pacific-Australasia	N
Lejeunea exilis (Reinw., Blume & Nees) Grolle	Lejeuneaceae	AK 313699	Malesia-Pacific-Australasia	N
Lejeunea gracilipes (Taylor) Steph.	Lejeuneaceae	AK 313869	Australasian warm temperate and Pacific	Y
Lejeunea apiculata Sande Lac.	Lejeuneaceae	AK 305160	Malesia-Pacific-Australasia	Y
Lejeunea schusteri Grolle	Lejeuneaceae	AK 313187	NZ and Cook Islands	Y
Lejeunea hodgsoniana Grolle ex R.J.Lewington, Bever. & M.A.M.Renner	Lejeuneaceae	AK 313726	NZ endemic	Y
Lejeunea sp. (m)	Lejeuneaceae	AK 315261		
Lembidium nutans (Hook.f. & Taylor) Mitt.	Lepidoziaceae	AK 305276	NZ endemic	Y
Lepidolaena palpebrifolia (Hook.) Trevis	Lepidolaenaceae	AK 305071	NZ endemic	Y
Lepidolaena taylorii (Gottsche) Trevis.	Lepidolaenaceae	AK 305105	NZ endemic	Y
Lepidolejeunea integristipula (Jack. & Steph.) R.M.Schust.	Lejeuneaceae	AK 5644 p.p.	Malesia-Pacific-Australasia	N
Lepidozia elobata R.M.Schust.	Lepidoziaceae	AK 305119	NZ endemic	Y
Lepidozia laevifolia (Hook.f. & Taylor) Gottsche, Lindenb, & Nees var. *laevifolia*	Lepidoziaceae	AK 305616	Australasian temperate	Y
Lepidozia spinosissima (Hook.f. & Taylor) Mitt.	Lepidoziaceae	AK 305217	NZ endemic	Y
Leptolejeunea australis Steph.	Lejeuneaceae	AK 315273	Australasian temperate	Y
Lobatiriccardia coronopus subsp. *australis* (R.M.Schust.) Nebel	Aneuraceae	AK 305087	NZ endemic	Y
Lopholejeunea knightii Steph.	Lejeuneaceae	AK 315277	NZ endemic	Y
**Lunularia cruciata* (L.) Dumort.	Lunulariaceae	AK 305102	Introduced	Y
Marchantia berteroana Lehm. & Lindenb.	Marchantiaceae	AK 305156	Malesia-Pacific-Australasia	Y
Marchantia foliacea Mitt.	Marchantiaceae	AK 325538	Australasian temperate	Y
Marchantia pileata Mitt.	Marchantiaceae	AK 221959	Australasian temperate	Y
Metalejeunea cucullata (Reinw., Blume & Nees) Grolle	Lejeuneaceae	AK 229527	Australasian temperate	Y
Metzgeria furcata (L.) Dumort.	Metzgeriaceae	AK 305280	cosmopolitan	Y
Monoclea forsteri Hook.	Monocleaceae	AK 325476	NZ endemic	Y

Species	Family	Voucher	Generalised distribution	Mainland NZ occurrence
Neolepidozia patentissima (Hook.f. & Taylor) E.D.Cooper var. *patentissima*	Lepidoziaceae	AK 305612	Australasian temperate	Y
Neolepidozia praenitens (Lehm. & Lindenb.) E.D.Cooper var. *praenitens*	Lepidoziaceae	AK 305611	NZ endemic	Y
Notoscyphus lutescens (Lehm. & Lindenb.) Mitt.	Acrobolbaceae	AK 325635	Tropical	N
Pallavicinia xiphoides (Hook.f. & Taylor) Trevis.	Pallaviciniaceae	AK 305218	Australasian temperate	Y
Paracromastigum furcifolium (Steph.) R.M.Schust.	Lepidoziaceae	AK 305295	NZ endemic	Y
Phaeomegaceros coriaceus (Steph.) R.J.Duff, J.C.Villareal, Cargill & Renzaglia	Dendrocerotaceae	AK 234047	NZ endemic	Y
Phaeoceros carolinianus (Michx.) Prosk.	Anthocerotaceae	AK 313859	Australasian temperate	Y
Phaeoceros delicatus E.O.Campb. & Outred	Anthocerotaceae	AK 325475	NZ endemic	Y
Plagiochasma rupestre (J.R.Forst. & G.Forst.) Steph.	Atyoniaceae	AK 305302	Australasian temperate	Y
Plagiochila alta Steph	Plagiochilaceae	AK 325477	Pacific	N
Plagiochila annotina Lindenb.	Plagiochilaceae	AK 305077	NZ endemic	Y
Plagiochila banksiana Gottsche	Plagiochilaceae	AK 305073	Australasian temperate	Y
Plagiochila pacifica Mitt.	Plagiochilaceae	AK 305197	Pacific	N
Podomitrium phyllanthus (Hook.) Mitt.	Pallaviciniaceae	AK 305286	Australasian temperate	Y
Porella amoena (Colenso) W.Martin	Porellaceae	AK 305106	Australasian temperate	Y
Porella sp. nov.	Porellaceae	AK 325688	NZ and Fiji	N
Psiloclada clandestina Mitt.	Lepidoziaceae	AK 305207	Malesia-Pacific-Australasia	Y
Radula allisonii Castle	Radulaceae	AK 313885	NZ endemic	Y
Radula cuspidata Steph.	Radulaceae	AK 305196	NZ endemic	Y
Radula javanica Gottsche, Lindenb. & Nees	Radulaceae	AK 313206	Malesia-Pacific-Australasia	N
Radula novae-hollandiae Hampe ex Lehm.	Radulacae	AK 315260	Australasian temperate	N
Radula plicata Mitt.	Radulaceae	AK 313882	NZ endemic	Y
Reboulia hemisphaerica subsp. *australis* R.M.Schust.	Aytoniaceae	CHR 595563	Australasian temperate	Y
Riccardia alba (Colenso) E.A.Brown	Aneuraceae	AK 305083	NZ and Lord Howe Island	Y
Riccardia aff. *wattsiana*	Aneuraceae	AK 305772		
Schistochila kirkiana Steph.	Schistochilaceae	AK 313211	NZ endemic	Y
Siphonolejeunea nudipes (Hook.f. & Taylor) Herzog var. *nudipes*	Lejeuneaceae	AK 305167	Australasian temperate	Y
Siphonolejeunea sp. nov.	Lejeuneaceae	AK 313693	NZ endemic	Y
Spruceanthus olivaceus (Hook.f. & Taylor) X.Q.Shi, R.L.Zhu & Gradst.	Lejeuneaceae	AK 315253	NZ endemic	Y
Spruceanthus planiuscula (Mitt.) X.Q.Shi, R.L.Zhu & Gradst.	Lejeuneaceae	CHR 161785	Malesia-Pacific-Australasia	N
Spruceanthus thozetianus (Gottsche & F.Muell.) B.M.Thiers & Gradst.	Lejeuneaceae	AK 313178	Australasian and PNG	N
Symphyogyna hymenophyllum (Hook.) Mont. & Nees	Pallaviciniaceae	AK 305221	Australasian temperate	Y
Symphyogyna subsimplex Mitt.	Pallaviciniaceae	AK 305158	NZ endemic	Y
Symphyogyna undulata Colenso	Pallaviciniaceae	AK 305220	NZ endemic	Y
Targionia hypophylla L.	Targioniaceae	AK 305116	Australasian temperate	Y
Telaranea herzogii (E.A.Hodgs.) E.A.Hodgs.	Lepidoziaceae	AK 305107	Australasian temperate	Y
Triandrophyllum subtrifidum (Hook.f. & Taylor) Fulford & Hatcher	Herbertaceae	AK 313889	Australasian temperate	Y
Trichocolea mollissima (Hook.f. & Taylor) Gottsche	Trichocoleaceae	AK 305274	Australasian temperate	Y
Trichocolea rigida R.M.Schust.	Trichocoleaceae	AK 305281	Australasian temperate	Y
Tricholepidozia lindenbergii var. *complanata* (J.J.Engel & G.L.Merr.) E.D.Cooper	Lepidoziaceae	AK 305305	Australasian temperate	Y
Tricholepidozia lindenbergii (Gottsche) E.D.Cooper var. *lindenbergii*	Lepidoziaceae	AK 305309,	Australasian temperate	Y
Tricholepidozia tetradactyla (Hook.f. & Taylor) E.D.Cooper	Lepidoziaceae	AK 305617	NZ endemic	Y
Zoopsidella caledonica (Steph.) R.M.Schust.	Lepidoziaceae	AK 305219	NZ and New Caledonia	Y
Zoopsis argentea (Hook.f. & Taylor) Gottsche, Lindenb. & Nees var. *argentea*	Lepidoziaceae	AK 305208	Australasian temperate	Y
Zoopsis leitgebiana (Carrington & Pearson) Bastow	Lepidoziaceae	AK 305165	Australasian temperate	Y

Table 2. Occurrences of hornwort and liverwort species on islands of the Kermadec Islands group.

Kermadec Hornwort and Liverwort Distribution						
	North Meyer	South Meyer	Raoul	Macauley	Cheeseman	L'Esperance
Altitude (m)	122	99	518	238	61	70
Area (ha)	12	12	2943	324	8	5
Acrobolbus knightii			+			
Acrolejeunea mollis			+			
Acrolejeunea pycnoclada subsp. *pycnoclada*			+			
Acrolejeunea securifolia subsp. *securifolia*			+			
Allisoniella recurva			+			
Anthoceros sp.			+			
Asterella australis				+		
Balantiopsis diplophylla var. *diplophylla*			+			
Bazzania adnexa			+			
Bazzania novae-zelandiae			+			
Bazzania tayloriana			+			
Ceramanus perfragilis			+			
Ceratolejeunea belangeriana			+			
Cheilolejeunea ceylanica			+			
Cheilolejeunea mimosa			+			
Cheilolejeunea parvidens			+			
Cheilolejeunea trifaria			+			
Cheilolejeunea sp. (a)			+			
Cheilolejeunea sp. (k)			+			
Chiloscyphus excisifolius			+			
Chiloscyphus lentus			+			
Chiloscyphus rupicola			+			
Chiloscyphus semiteres			+	+		
Chiloscyphus subporosus			+			
Chiloscyphus aff. *bispinosus*			+			
Chiloscyphus aff. *novae-zeelandiae*			+			
Cololejeunea cucullifolia	+					
Cryptolophocolea helmsianus			+			
Cryptolophocolea mittenianus			+			
Cumulolejeunea ocellata			+			
Cuspidatula monodon			+			
Dendroceros granulatus			+			
Dendromastigophora flagellifera			+			
Dinckleria fruticella			+			
Drepanolejeunea aucklandica			+			
Drepanolejeunea vesiculosa subsp. *vesiculosa*			+			
Drucella integristipula			+			
Dumortiera hirsuta			+	+		
Echinolejeunea papillata			+			
Frullania apiculata			+			
Frullania falciloba			+			
Frullania fugax			+			
Frullania pentapleura			+	+	+	+
Frullania spinfera			+			
Frullania aff. *spinfera*			+			
Frullania aff. *rostellata*			+			
Frullania aff. *rostrata*			+			
Frullania aff. *squarrosula*			+			
Frullania sp. subgenus *Microfrullania*			+			
Frullania sp. subgenus *Trachycolea*			+			
Heteroscyphus allodontus			+			
Heteroscyphus ammophilus			+			
Heteroscyphus argutus			+			

Kermadec Hornwort and Liverwort Distribution						
	North Meyer	South Meyer	Raoul	Macauley	Cheeseman	L'Esperance
Heteroscyphus cuneistipulus			+			
Heteroscyphus coalitus			+			
Heteroscyphus echinellus			+			
Heteroscyphus fissistipus var. *multispinus*			+			
Heteroscyphus lingulatus			+			
Heteroscyphus supinus			+			
Heteroscyphus triacanthus var. *triacanthus*			+			
Hymenophyton flabellatum			+			
Isotachis lyallii			+			
Kurzia moniliformis			+			
Kurzia quinquespina				+		
Lamellocolea granditexta			+			
Lejeunea anisophylla			+			
Lejeunea exilis			+			
Lejeunea gracilipes			+			
Lejeunea apiculata			+			
Lejeunea schusteri			+			
Lejeunea hodgsoniana		+	+			
Lejeunea sp. (m)			+			
Lembidium nutans			+			
Lepidolaena palpebrifolia			+			
Lepidolaena taylorii			+			
Lepidolejeunea integristipula			+			
Lepidozia elobata			+			
Lepidozia laevifolia var. *laevifolia*			+			
Lepidozia spinosissima			+			
Leptolejeunea australis			+			
Lobatiriccardia coronopus subsp. *australis*			+			
Lopholejeunea knightii			+	+		
**Lunularia cruciata*			+	+		
Marchantia berteroana			+	+		
Marchantia foliacea				+		
Marchantia pileata			+	+		
Metalejeunea cucullata			+			
Metzgeria furcata			+			
Monoclea forsteri			+			
Neolepidozia patentissima var. *patentissima*			+			
Neolepidozia praenitens var. *praenitens*			+			
Notoscyphus lutescens			+			
Pallavicinia xiphoides			+			
Paracromastigum furcifolium			+			
Phaeomegaceros coriaceus			+			
Phaeoceros carolinianus			+			
Phaeoceros delicatus			+			
Plagiochasma rupestre			+	+		
Plagiochila alta			+			
Plagiochila annotina			+			
Plagiochila banksiana			+			
Plagiochila pacifica			+			
Podomitrium phyllanthus			+			
Porella amoena			+			
Porella sp. nov.			+			
Psiloclada clandestina			+			
Radula allisonii			+			
Radula dentifolia			+			
Radula javanica			+			

Kermadec Hornwort and Liverwort Distribution						
	North Meyer	South Meyer	Raoul	Macauley	Cheeseman	L'Esperance
Radula novae-hollandiae			+			
Radula plicata			+			
Reboulia hemisphaerica subsp. *australis*.			+	+		
Riccardia alba			+			
Riccardia aff. *wattsiana*			+			
Schistochila kirkiana			+			
Siphonolejeunea nudipes			+	+		
Siphonolejeunea sp. nov.			+			
Spruceanthus olivaceus			+			
Spruceanthus planiusculus			+			
Spruceanthus thozetianus			+			
Symphyogyna hymenophyllum			+			
Symphyogyna subsimplex			+			
Symphyogyna undulata			+			
Targionia hypophylla			+	+		
Telaranea herzogii			+			
Tricholepidozia lindenbergii var. *complanata*			+			
Tricholepidozia lindenbergii var. *lindenbergii*			+			
Tricholepidozia tetradactyla			+			
Triandrophyllum subtrifidum			+			
Trichocolea mollissima			+			
Trichocolea rigida			+			
Zoopsidella caledonica			+			
Zoopsis argentea var. *argentea*			+			
Zoopsis leitgebiana			+			
134 taxa	1	1	130	10	1	1

Islands and rocks lacking hornworts and liverworts

Hornworts and liverworts are apparently absent from the Herald Islets, Napier, Nugent, Milne, Dougal and Egeria Rocks, Hazard Islet, "Hazardette", and Curtis Island. As expected, the much larger, physiographically diverse and densely forested Raoul Island has the largest flora (130 taxa) and is also the only island to support any hornworts, followed by the next largest island Macauley (14 taxa). Interestingly, despite their forested state, North and South Meyer collectively supported only two liverworts, whilst the sparsely vegetation Cheeseman Island and L'Esperance Rock had one species (*Frullania pentapleura*). With the exception of Curtis Island which was not landed on (see de Lange 2012) and which may support hornworts and liverworts because it does have a small moss flora, the survey coverage of the Kermadec Islands is now fairly complete. Nevertheless, several key parts of Raoul Island still need critical investigation, particularly the caldera floor, fumaroles and craters, locations which for safety reasons remained out of bounds during the 2009 and 2011 visits.

The Northern Kermadec Island Group

The Meyer Islands and Herald Islets

The Meyer Islands (Fig. 5) and Herald Islets (Fig. 6) comprise a cluster of 13 vegetated islands, islets and rock stacks and a further 21 low-lying non-vegetated rock stacks and associated exposed reefs. The largest islands are The Meyers, which support a forest cover dominated by Kermadec pohutukawa (*Metrosideros kermadecensis*) and Kermadec ngaio (*Myoporum rapense* subsp. *kermadecensis* (W.R.Sykes) Chinnock) (Fig. 7). Napier, Nugent and Dayrell have a similar though very much smaller vegetation cover. The vegetation of the Chanters was described as one dominated by Kermadec ngaio (reported as *M. obscurum*) by Sykes (1977). However, when PdL visited these outer islands and islets in 2011, the vegetation was only just starting to recover from the passage of Tropical Cyclone Bune (de Lange 2011b). Consequently, much of the plant cover was either dead, or the trees and shrubs stripped completely of their foliage, while the ground cover had mostly been washed, blown or burned off leaving mostly bare earth. It seems likely that this cyclone damage will have contributed to the depauperate liverwort flora recorded from these islands and islets during the 2011 visit.

Figure 5. The Meyers as viewed from Fishing Rock, Raoul Island. North Meyer (left hand side of image), South Meyer (right hand side of image) with Egeria Rock in foreground (image: Peter J. de Lange).

Figure 6. A portion of the Herald Islets (The Chanters) as viewed looking north from North Meyer (image: Peter J. de Lange).

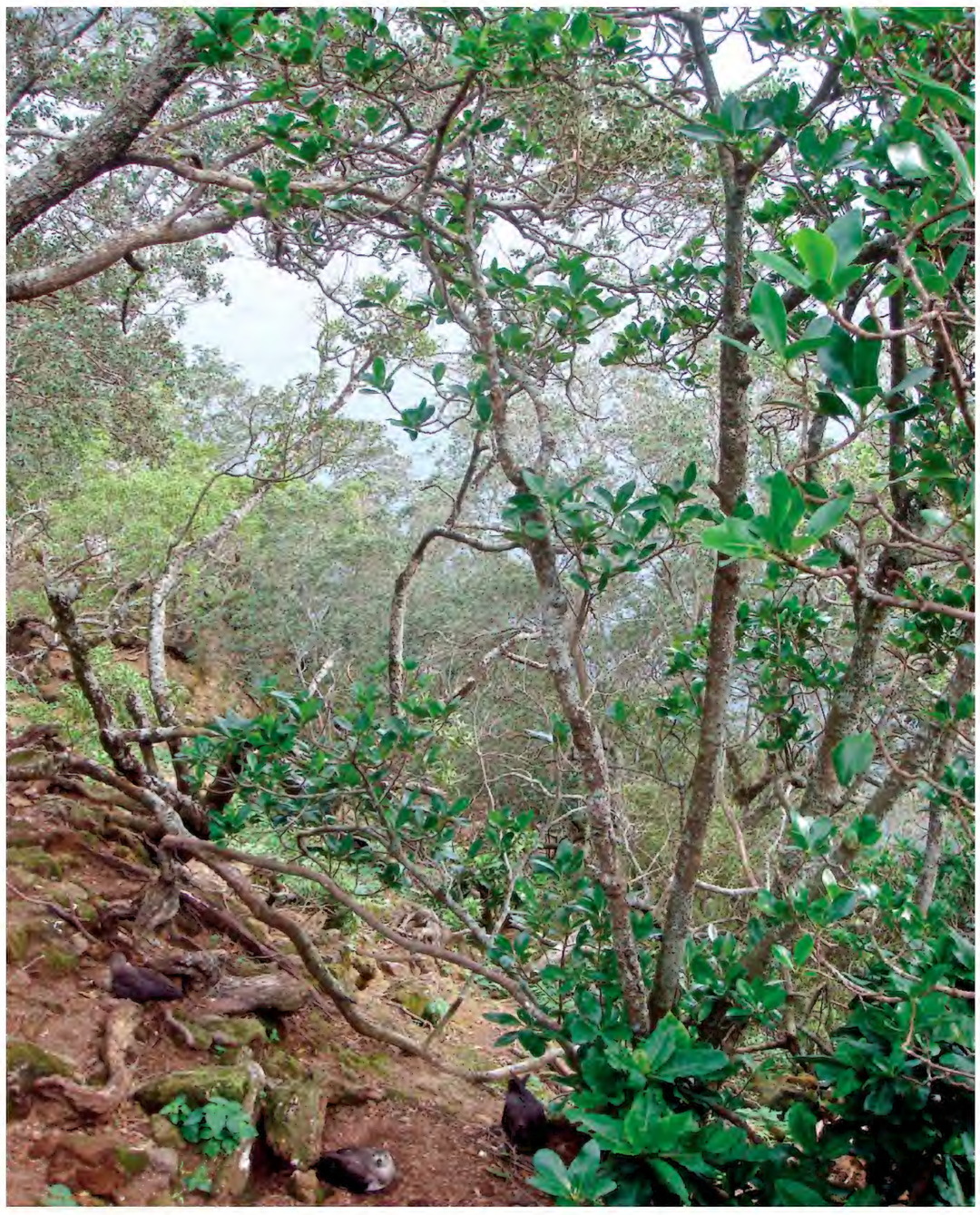

Figure 7. Forest interior, South Meyer. The dominant forest tree is *Metrosideros kermadecensis* followed by *Myoporum rapense* subsp. *kermadecense* with occasional *Corynocarpus laevigatus*. The bare ground in this image is the result of seabird activity, though acerbated by the impact of Cyclone Bune (image: Peter J. de Lange).

Only two liverwort species were found on The Meyers; *Lejeunea hodgsoniana*, found only on North Meyer in a few locations on shaded rocks and the basal portion of the trunks of Kermadec pohutukawa and ngaio, and *Cololejeunea cucullifolia* which was found near the summit of South Meyer growing on the sheltered portion of the trunk of a very large Kermadec pohutukawa. A notable and unexplained absence was *Frullania*, so much a feature of similar forested vegetation on nearby Raoul Island. Despite the likely impact of Cyclone Bune on the liverwort flora of these outer islands, these islands and islets may naturally have a depauperate hepatic flora, as 22 moss species were recorded from the islands and islets during the same survey (de Lange & Beever 2015).

Raoul Island

Raoul Island has a vegetation cover entirely dominated by Kermadec pohutukawa. However, based on differences in the canopy and subcanopy composition of mostly vascular plants (and also the abundance of epiphytic mosses), Oliver (1910) partitioned the island's forest cover into two main types, a 'dry' and a 'wet' forest type (Fig. 8, 9). Sykes (1977) maintained this distinction. The 'dry' forest was typified by the local dominance of *Myrsine kermadecensis* Cheeseman within the understory (and at times canopy) of the otherwise dominant Kermadec pohutukawa forest, and also by the absence of hutu (*Ascarina lucida* var. *lanceolata* (Hook.f.) Allan) and of the epiphytic moss *Papillaria crocea* (see comments by Sykes 1977). Conversely the 'wet' forest type has mahoe (*Melicytus ramiflorus* J.R.Forst. et G.Forst.), and hutu, with abundant *Papillaria crocea,* and *Myrsine* notably scarce. These basic forest types are still recognised today, despite changes in forest composition following the successful goat eradication in 1983, and rising dominance of nikau (*Rhopalostylis baueri* (Seem.) H.Wendl. et Drude) (Parkes 1984; de Lange & Stanley 1999; de Lange & Havell 2009) (Fig. 10).

With 130 taxa (Table 1) Raoul Island supports the greatest liverwort diversity in the archipelago. It is also the only island known to support hornworts (five taxa, *Anthoceros* sp. indet. *Dendroceros granulatus Phaeomegaceros coriaceus*, *Phaeoceros carolinianus*, *Phaeoceros delicatus*). Of the 134 recorded liverworts, all but 4 are known in the archipelago only from Raoul (Table 1). One of the liverworts reported from Raoul *Lunularia cruciata* is regarded as naturalised. This species is abundant on Raoul Island, along the various tracks and roads maintained by DOC, and around the accommodation buildings and huts. It is also reasonably common within those areas visited by people undertaking weed control and track maintenance. *Lunularia* also occurs locally on Macauley Island, and it seems that it was introduced to that island from Raoul Island (de Lange 2015a,b,c).

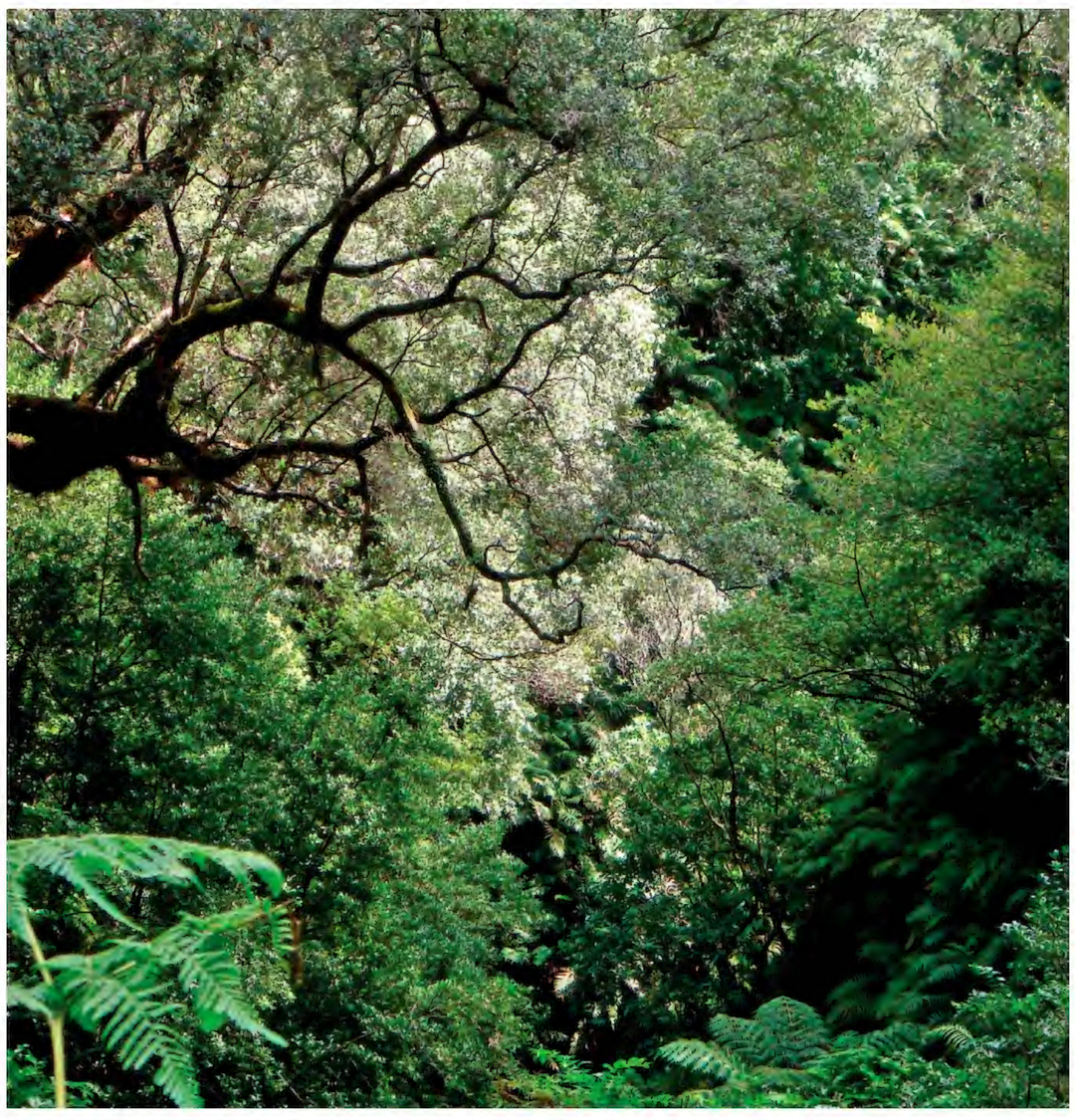

Figure 8. 'Dry' forest interior, near the base of Ravine 8, Raoul Island. The forest canopy is almost exclusively *Metrosideros kermadecensis* with a subcanopy of *Myrsine kermadecensis* (image: Peter J. de Lange).

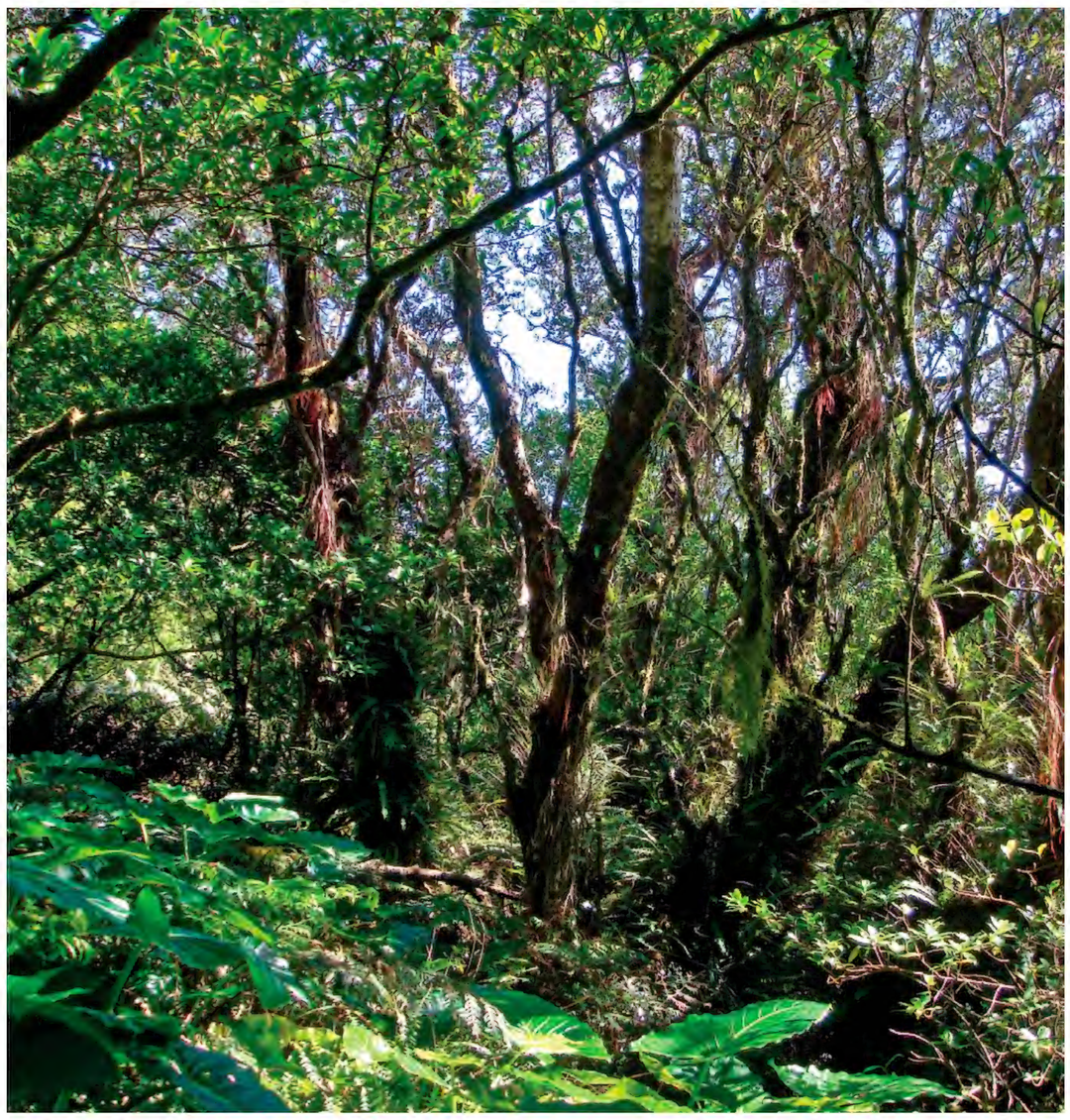

Figure 9. 'Wet' forest interior, upper slopes of Moumoukai, Raoul Island. The forest canopy here though still dominated by *Metrosideros kermadecensis* has other canopy emergents including *Ascarina lucida* var. *lanceolata*, *Melicytus ramiflorus* subsp. *ramiflorus*, and increasingly *Alsophila kermadecensis* and *Pseudopanax kermadecensis* (image: Peter J. de Lange).

Figure 10. *Rhopalostylis baueri*, mid slopes of Moumoukai, Raoul Island, has, especially following the eradication of browsing animals, increased its presence across the island, and indications are that it is forming its own distinct vegetation association (image: Peter J. de Lange).

Despite the high liverwort diversity of Raoul Island, in a pattern comparable to the mosses (de Lange & Beever 2015) only a few of the liverworts recorded from there are common, most seem to be naturally scarce. Again, as with the mosses (de Lange & Beever 2015) there also appears to be a shift in liverwort assemblages moving north to south across the island. The most common (or at least visually obvious) liverworts on Raoul are *Chiloscyphus semiteres* var. *semiteres*, an as yet unnamed segregate of *Frullania rostrata* (Hook.f. et Taylor) Hook.f. et Taylor treated as "*Frullania* species B" in Carter et al. (2017), *Heteroscyphus argutus* (Fig. 11), *Lejeunea gracilipes*, *Lepidozia elobata*, *Lopholejeunea knightii, Plagiochila pacifica* (Fig. 12) and *Tricholepidozia lindenbergii*. However, some liverworts, such as *Marchantia pileata* and the two species of *Riccardia* are also common, though only in the ravines of the northern part of the island. The upper 'wet' forest running along the crater walls and toward Mahoe and Smiths Bluff is where *Radula javanica* (Fig. 13) is especially common, though it also resides around the seepages and small natural springs located within the ravines scattered along the north-western portion of the island.

Figure 11. *Heteroscyphus argutus* near Prospect, Raoul Island. This species is one of the more conspicuous of the Lophocoleaceae on account of its size, and characteristically 'washed' out colour. This species is common throughout both 'dry' and 'wet' forest associations on the island (image: Peter J. de Lange).

Figure 12. *Plagiochila pacifica* on the lower trunk of *Rhopalostylis baueri*, Moumoukai, Raoul Island. This species, seen here growing with *Radula javanica*, was once considered endemic to Raoul Island, is probably the most obvious of the island's liverworts by virtue of its size and abundance in the 'wet' forest of that island (image: Peter J. de Lange).

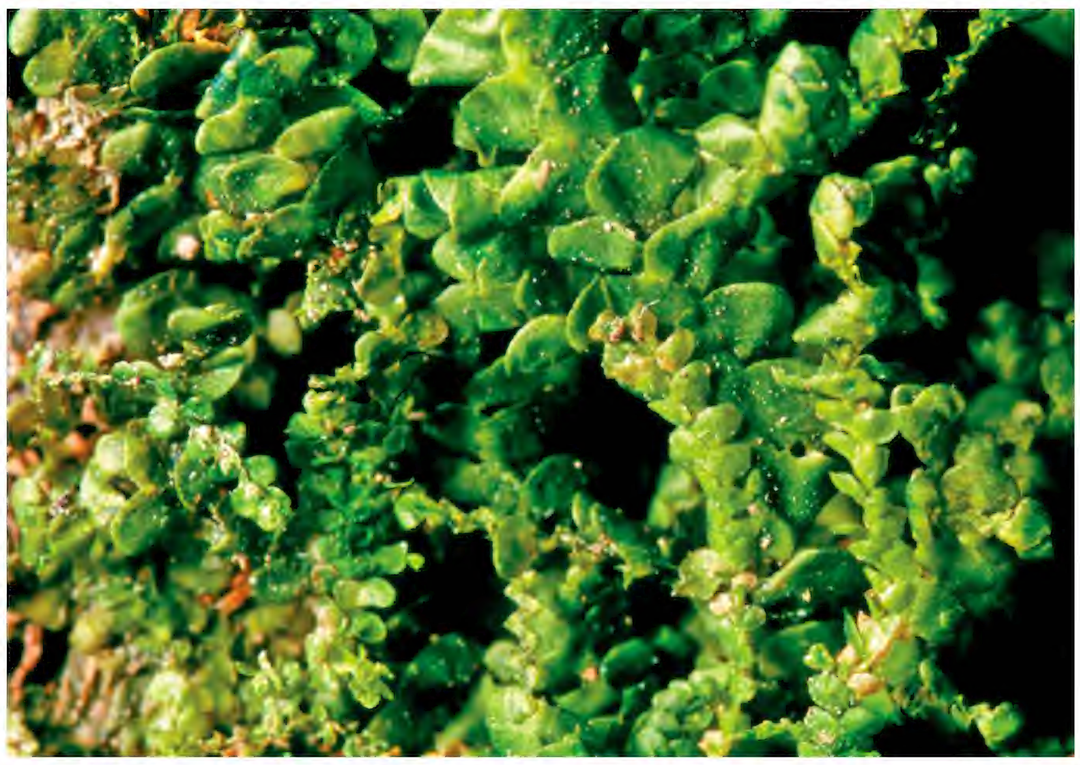

Figure 13. *Radula javanica* (as *R. cordiloba* subsp. *erigens*) was once considered very uncommon on Raoul Island. It is now known to be quite widespread, often growing with *Plagiochila pacifica* (image: John E. Braggins).

Some of these patterns may reflect that the vegetation of Raoul Island, natural volcanic, earthquake and cyclonic perturbations aside, is still recovering from over one hundred years of modification by humans and introduced browsing animals (Sykes 1969; Parkes 1984; de Lange & Galloway 2015). Browsing animals undoubtedly had a tremendous impact on the cryptogamic flora of Raoul Island through opening up habitats, thereby increasing evapotranspiration and available light; through the physical destruction of colonies, and by decreasing soil nutrient levels and soil cycling through the loss of seabird-induced pedoturbation following the eradication of seabird nesting colonies. Therefore, the removal of goats 28 years ago (see Parkes 1984), and later both cats and rats in 2002 (de Lange & Havell 2009), will have had and will continue to have long-term consequences for the flora, fauna, and vegetation recovery of Raoul (Sykes 1969; Parkes 1984; de Lange & Beever 2015).

Aside from animal eradications, the extirpation of a range of environmentally damaging weed species, and the ongoing intensive long-term management of others, mean that major disturbance to the indigenous vegetation of Raoul is likely to be affected only by the aforementioned natural stochastic events (earthquakes, volcanism, and tropical cyclones). While these are potentially very destructive to standing vegetation, such events have undoubtedly contributed to the evolving flora of the islands in the past by creating new, sometimes novel, habitats for colonisation, releasing fresh nutrients, and in the case of tropical cyclones "seeding" the Kermadecs with the propagules of fungi and plants (de Lange & Galloway 2015). Lastly, the role of seabirds in the vegetation recovery and enrichment of the Raoul Island cryptogamic flora needs further consideration, as in the past the island was covered in an array of ground nesting and burrowing seabirds (Cheeseman 1889, 1891; Iredale 1910, 1913, 1914; Bell 1911, 1912; Oliver 1912; Bacon 1957; Sorenson 1964; Straubel 1954; Merton 1970), which not only facilitated soil turn-over and nutrient enrichment but also potentially acted as dispersal agents for plants and fungi from other island groups (see comments by de Lange et al. 2004; de Lange & Galloway 2015).

The Southern Kermadec Island Group

Macauley Island

The largest island of the Southern Kermadec Island Group, Macauley once had a low forest cover of what was probably Kermadec ngaio (Sykes 1977; Barkla et al. 2008; de Lange 2015a). Fairly early on in the island's recorded history pigs and goats were liberated there, and, while the pigs did not thrive, the goats had a serious impact on that island's vegetation cover before they were at last eradicated in 1970 (Sykes 1977). As such the vegetation of Macauley Island is still recovering; currently it is mostly vegetated by dense, almost impenetrable *Hypolepis* fernland and *Cyperus* sedgeland (Fig. 14), with small pockets of Kermadec ngaio shrub land and 'forest' present on the cliff faces and ravines near Mt Haszard (Fig. 15), the highest part of that island (see Barkla et al. 2008; de Lange 2015a). Although most of the plateau is now choked by a dense, monospecific fernland, the ravines (Fig. 16), gullies and canyons which drain the plateau are mostly free of *Hypolepis*. Also on the steep, eroding scoria cliffs of the Mt Haszard crater system, *Hypolepis* is less common, and it is in these places where liverworts have been found.

Figure 14. Macauley Island looking across the inland crater and the plateau to Hazard Island. The dominant vegetation during the May 2011 survey of the island was *Hypolepis dicksonioides* fernland. The vegetation forms a dense, almost impenetrable mass in places 3 m deep through which land and sea birds are unable to travel. This vegetation probably in part explains the paucity of hepaticae on this island (image: Peter J. de Lange).

Figure 15. The seaward crater below Mt Hazard, Macauley Island has all but eroded. However, the rubble slopes and tuff cliffs support a range of hepatics of which the most common is *Plagiochasma rupestre*. Surprisingly the dense *Myoporum* forest supported only occasional specimens of *Siphonolejeunea nudipes* var. *nudipes* (image: Peter J. de Lange).

Figure 16. Access Gully – the main route to the plateau of Macauley Island when making sea landings had a small population of *Lunularia cruciata* that we surmise was probably introduced from Raoul or New Zealand by past landing parties (image: Peter J. de Lange).

Fourteen liverworts have now been recorded from Macauley (de Lange 2015a) which next to Raoul Island is the largest number for any of the islands (Table 1). Of the 14 liverworts recorded there, *Asterella australis*, and *Marchantia foliacea* are so far known in the Kermadec Islands only from Macauley Island (Table 2; de Lange 2015a). The most commonly encountered species is *Plagiochasma rupestre* var. *rupestre* which is abundant along the scoriaceous dacitic-tholeiitic basalt cliff faces, and overhangs on the seaward side of Mt Haszard. In these places it is sometimes found in association with *Frullania pentapleura* and *Siphonolejeunea nudipes* var. *nudipes*. *Lunularia cruciata* is locally common along the walls of Access Gully. This species was not reported from Macauley Island until May 2011, and as it was only seen in sites used to access the island by recent landing parties it is likely a recent introduction to the island, possibly even from Raoul Island (see above). Three species of *Marchantia* (*M. berteroana*, *M. foliacea* and *M. pileata*) have now been recorded from Macauley Island though none is common. Perhaps more surprising is the occurrence of the moisture-loving *Dumortiera hirsuta* a species first reported for the island in collections made by Sykes during visits to the island in 1966 and 1970 (see Campbell in Sykes 1977), and which is still found there in the Grand Canyon ravine.

Cheeseman Island

One liverwort, *Frullania pentapleura* was collected from Cheeseman Island (Table 2) where it was extremely uncommon (de Lange 2015b). Bryophytes had not been previously reported from Cheeseman Island which has only been occasionally visited on account of its difficult landing (de Lange 2015b). Despite the paucity of visits it does not seem likely that Cheeseman Island (Fig. 17) would ever have had a diverse liverwort flora; the island is too dry, poorly vegetated, and low in microhabitat diversity. Nevertheless, 11 species of moss were recorded from the island during the same landing (de Lange 2015b; de Lange & Beever 2015) and, in that context it is perhaps surprising that none of the more drought-resistant thalloid liverworts common on nearby Macauley Island (particularly *Marchantia pileata* and *Plagiochasma rupestre*) were found on Cheeseman Island (de Lange 2015b). As the vegetation of Cheeseman Island had also been severely damaged by the passage of Tropical Cyclone Bune some 45 days prior to the islands visit (de Lange 2012, 2015a,b,c), it is possible that liverworts may have been temporarily eliminated from the island, or reduced to such small numbers that they were overlooked.

Figure 17. Cheeseman Island as viewed from the north (image: Peter J. de Lange).

L'Esperance Rock

Rising to 70 m a.s.l L'Esperance Rock (Fig. 18) is the most isolated of the Kermadec Islands Group and the least vegetated (de Lange 2015c). Only ten vascular plants make up its flora, including *Senecio esperensis* which is endemic to that rock (Sykes 1971, 1977; de Lange et al. 2015). Despite being sparsely vegetated, and at the time of landing (May 2011) even more so because of cyclone damage (de Lange 2012), one liverwort, *Frullania pentapleura*, was found near the northern end of the main summit saddle of the rock (Table 1).

Figure 18. L'Esperance Rock as views from the north-west (image: Peter J. de Lange).

Biogeographic considerations

More than half the indigenous species of the Kermadec Islands belong to just three families, Lejeuneaceae, Lepidoziaceae and Lophocoleaceae, which are together represented by 71 species. The strong representation of Lejeuneaceae is consistent with floras of lowland forest habitats in tropical and subtropical climates globally, but the relatively high representation of Lepidoziaceae and Lophocoleaceae are anomalous, particularly the generic diversity represented on the Kermadec Islands within

Lepidoziaceae, with 13 genera present. The Kermadec Island flora is relatively depauperate in Frullaniaceae, a family usually co-dominant with Lejeuneaceae in terms of species diversity. These features of the Kermadec flora may be explained to some degree by the contributions surrounding land masses have made to the Kermadec Islands flora by long-distance dispersal. Indeed, the entire Kermadec Islands flora is derived by long-distance dispersal, as befits the relatively young age of the group which dates to the late Pleistocene (c. 0.5–1.5 mya, Brothers & Searle 1970; Lloyd & Nathan 1981). Notably there are no liverworts or hornworts endemic to the Kermadec Island Group.

The liverwort flora of the Kermadec Islands has strong links to New Zealand. Of the 122 taxa now recorded for the Kermadecs whose distribution has been documented, 105 also occur on the New Zealand mainland, and 42 are endemic to the New Zealand Botanical Region (Table 1), with occurrences on Raoul Island reflecting northern-most distributional outliers. These patterns strongly suggest that most of the Kermadec Island flora has been sourced from New Zealand to the south-west, which is reflected in the contribution made by the families Lepidoziaceae and Lophocoleaceae, both of which are diverse in lowland forest habitats of New Zealand, to the Kermadec Island flora (Table 1). Occurrences of some species on Raoul Island are unusual, particularly for those associated with cool hyperhumid forest environments whose distribution contracts upward in elevation with decreasing latitude, including *Dendromastigophora flagellifera, Echinolejeunea papillata, Lepidolaena palpebrifolia,* and *Lepidozia spinosissima*. In the northern part of their distributions on New Zealand these species are more or less confined to higher elevation sites associated with summits and elevated plateau. Most of the other New Zealand endemic species are widespread in lowland forest habitats, their occurrence on Kermadec Islands is supported by similar microhabitats and indeed similar assemblages of species. Why these species have dispersed as far as the Kermadec Islands but not further into the Pacific Region may warrant investigation and explanation once their absence from islands further to the north has been confirmed. The confinement of these species to the New Zealand Botanical Region does not seem to be for want of dispersibility, given they have traversed just over half the distance separating New Zealand from the Tonga group, and Fiji.

In contrast to the contribution of species from the south, there has been only limited contribution of species from the west or the north of the Kermadec Islands. Only 16 of the species on the Kermadec Islands occur either nowhere else in the New Zealand Botanical Region, or only on the Chatham Islands (Table 3). Another, *Heteroscyphus argutus*, also occurs on Mayor Island, off the Bay of Plenty coast, and the Chatham Islands but is not yet recorded from the North Island though its occurrence there should be anticipated. Because of its occurrence proximate to the North Island we have not included it in Table 3, below. A similar number of moss species occur on the Kermadec Islands, but not on the New Zealand mainland (de Lange & Beever 2015).

Table 3. Tropical liverworts of the Kermadec Islands. The two species marked with an asterisk also occur on the Chatham Islands.

Acrolejeunea pycnoclada (Taylor) Schiffn. subsp. *pycnoclada*
Ceratolejeunea belangeriana (Gottsche) Steph.
Cheilolejeunea ceylanica (Gottsche) R.M.Schust. & Kachroo
Cheilolejeunea trifaria (Reinw., Blume & Nees) Mizut.
Drepanolejeunea vesiculosa Herzog subsp. *vesiculosa*
Frullania apiculata (Reinw., Blume & Nees) Dumort.
**Lejeunea anisophylla* Mont.
Lejeunea exilis (Reinw., Blume & Nees) Grolle
Lepidolejeunea integristipula (Jack. & Steph.) R.M.Schust.
Notoscyphus lutescens (Lehm. & Lindenb.) Mitt.
Plagiochila alta Steph
Plagiochila pacifica Mitt.
Porella sp. nov.
**Radula javanica* Gottsche, Lindenb. & Nees
Spruceanthus planiuscula (Mitt.) X.Q.Shi, R.L.Zhu & Gradst.
Spruceanthus thozetianus (Gottsche & F.Muell.) B.M.Thiers & Gradst.

Of the 16 species in Table 3, the Lejeuneaceae dominate, followed by minor contributions from the Frullaniaceae, Plagiochilaceae and Radulaceae. Most of these families are generally widespread in the tropical regions of Australasia, Malesia, and the Pacific and beyond and could have dispersed from any northerly quarter. Two have dispersed from the west, and warrant comment. *Radula novae-hollandiae* is confined to Australia south of the tropic of Capricorn, except for occurrences on Norfolk Island and Raoul Island (Pócs & Renner 2021). This species has dispersed to Raoul Island either directly from the Australian mainland, or from Norfolk Island.

Spruceanthus thozetianus is another species that has dispersed from the west, it occurs up the east coast of Australia, in Papua New Guinea and on Norfolk Island, and like *Radula novae-hollandiae* may have dispersed to Raoul Island from either the Australian mainland or Norfolk Island. In this checklist *Spruceanthus thozetianus* replaces *Thysananthus spathulistiulus*, recorded for the Kermadec Islands by Renner & de Lange (2011), who struggled to identify the single male specimen correctly. Field experience on the east coast of Australia since 2011 has made the identity of the Kermadec specimen clearer, and we update our determination accordingly. *Spruceanthus thozetianus* is variable in size and morphology on the Australian mainland

(Thiers & Gradstein 1989), and the scattered stems fall within this range, however without perianths our determination is qualified by caution.

Linkage with the flora of Norfolk Island, suggested by the shared occurrence of these two species may become stronger and clearer once the flora of Norfolk Island is documented. As yet there is no comprehensive treatment of the liverwort and hornwort flora for Norfolk Island.

Linkage between the Kermadec Islands and north-eastern Australia are evident in the moss flora of Kermadec Islands (de Lange & Beever 2015), but are not so evident in the liverwort and hornwort flora, it is possible that some of the under-determined entities included in our checklist will prove to be poorly known species that are shared with tropical Queensland, which has a more distinctive and diverse liverwort flora than generally appreciated from herbaria in the northern hemisphere from where much of the documentary work was, until relatively recently, produced. There are 12 under-determined taxa in our checklist, including six *Frullania*, two *Cheilolejeunea* and one *Lejeunea*. *Frullania* of Australasia have been subject to more than two decades of ongoing revision (e.g., von Konrat & Braggins 2001, 2003), which follow the studies of Hattori (1979a, 1979b, 1983). *Cheilolejeunea* are poorly documented for Australia, and the real diversity on the Australian continent will prove higher than the 24 species currently known from Australia (Renner et al. 2024). *Lejeunea* is also poorly documented, especially in the Tropical Biome of Australia, where further investigation of species boundaries is warranted.

That the Kermadec liverwort flora has such a strong affinity with the rest of New Zealand, and yet has a minor but biogeographically interesting tropical Pacific component, may reflect the main avenues for propagule dispersal to the islands. During winter the Kermadec Islands experience strong south-westerly air flows, while during the summer the wind direction changes to the north-east (Bannister & Blanchon 2003; Blanchon et al. 2012). Further, the seemingly anomalous eastern Australian liverwort occurrences on the Kermadecs may reflect uplift of propagules by tropical cyclones which are generated in that part of Pacific, and whose tracking regularly crosses the Kermadec Islands Group (Revell 1981; Terry 2007). But it is unusual that the contribution made by tropical liverwort and hornwort species to the Kermadec Islands flora is not greater. On that element comparison with other small islands at similar latitude, particularly Norfolk Island and Lord Howe Island will be particularly interesting.

Although further bryological survey of the islands will no doubt reveal overlooked taxa, there is now a sufficiently robust base line to enable examination of a changing bryophyte flora in relation to ongoing vegetation recovery of the islands, long distance dispersal of propagules from New Zealand and the wider Pacific, and the impact of the extreme natural disturbance events which periodically occur.

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References

Allan HH (1961) *Flora of New Zealand. Vol. I*. Government Printer. Wellington. 1085 pp.

Bacon A (1957) Raoul adventures. Reminiscences written at the age of 86 years. (Unpublished; copy held at Warkworth Area Office, Department of Conservation.) 32 pp.

Bannister JM, Blanchon DJ (2003) The lichen genus *Ramalina* Ach. (Ramalinaceae) on the outlying islands of the New Zealand geographic area. *Lichenologist* 35: 137–146.

Barkla JW, Dilks PJ, Greene TC, Griffiths R (2008) *Homalanthus polyandrus* (Euphorbiaceae) on Macauley Island, southern Kermadec Islands, with notes on that island's vascular flora. *New Zealand Journal of Botany* 46: 373–379.

Beever JE, Fife AJ, West CJ (1996) Mosses of the Kermadec Islands, northern New Zealand. *New Zealand Journal of Botany* 34: 463–471.

Bell RS (1911) Diary 1908 to 1911. (Unpublished; held at Alexander Turnbull Library/National Library. Wellington.)

Bell RS (1912) Breeding habits of white tern (*Gygis alba*) on Kermadec Group. *Emu* 12: 26–30.

Blanchon DJ, de Lange PJ, Bannister J (2012) Confirmation of *Ramalina microspora* Kremp. (Ramalinaceae: Ascomycota) for the Kermadec Islands. *Australasian Lichenology* 70: 30–35.

Braggins JE, Renner MAM, de Lange PJ (2014) Additions to the liverwort flora of the Kermadec Islands, New Zealand Botanical Region. *Telopea* 17: 183–194.

Cameron EK & Sykes WR (2015) *Pittosporum rangitahua* sp. nov., from Raoul Island, Kermadec Islands, northern New Zealand. *Auckland Museum Bulletin* 20: 253–262.

Campbell EO (1997) Some additions and alterations to the liverwort and hornwort flora of the Kermadec Islands. *New Zealand Botanical Society Newsletter* 49: 8–9.

Carter BE, Larraín J, Manukjanová A, Shaw B, Shaw AJ, Heinrichs J, de Lange, PJ, Suleiman M, Thouvenot L, von Konrat, M. (2017). Species delimitation and biogeography of a southern hemisphere liverwort clade, *Frullania* subgenus *Microfrullania* (Frullaniaceae, Marchantiophyta). *Molecular Phylogenetics and Evolution* 107: 16–26.

Cheeseman TF (1889) On some birds from the Kermadec Islands. *Transactions and Proceedings of the New Zealand Institute* 21: 121–124.

Cheeseman TF (1891) On the birds of the Kermadec Islands. *Transactions and Proceedings of the New Zealand Institute* 23: 216–226.

de Lange PJ (2011a) Kermadec Biodiscovery Expedition 2011 (Part II – The Meyers). *Trilepidea* 93: 3–8.

de Lange PJ (2011b) Kermadec Biodiscovery Expedition 2011 (Part III – The Herald Islets, Napier and Nugent). *Trilepidea* 94: 3–11.

de Lange PJ (2011c) Kermadec Biodiscovery Expedition 2011 (Part IV – Raoul Island). *Trilepidea* 95: 2–11.

de Lange PJ (2012) Kermadec Biodiscovery Expedition 2011 – The Southern Kermadec Islands Group. *Auckland Botanical Society* 67: 43–60.

de Lange PJ (2015a) Vegetation succession and flora of Macauley Island, Southern Kermadec Islands Group. *Auckland Museum Bulletin* 20: 207–230.

de Lange PJ (2015b) The flora and vegetation of Cheeseman Island, Southern Kermadec Islands Group. *Auckland Museum Bulletin* 20: 243–252.

de Lange PJ (2015c) The flora and vegetation of L'Esperance Rock, Southern Kermadec Islands Group. *Auckland Museum Bulletin* 20: 231–242.

de Lange PJ, Stanley RJ (1999) Kermadec koromiko (*Hebe breviracemosa*) comes back from the brink of extinction. *New Zealand Botanical Society Newsletter* 55: 9–12.

de Lange PJ, Scofield RP, Greene T (2004) *Achyranthes aspera* (Amaranthaceae) a new indigenous addition to the flora of the Kermadec Islands Group. *New Zealand Journal of Botany* 42: 167–173.

de Lange PJ, Havell DC (2009) Kermadec Koromiko (*Hebe breviracemosa*) – back from the brink of extinction. *New Zealand Botanical Society Newsletter* 97: 13–16.

de Lange PJ, Heenan PB, Norton DA, Rolfe JR, Sawyer JWD (2010) *Threatened plants of New Zealand*. Christchurch, Canterbury University Press. 471 pp.

de Lange PJ, Gardner RO, Sykes WR, Crowcroft GM, Cameron EK, Stalker F, Christian ML, Braggins JE (2005) Vascular flora of Norfolk Island: some additions and taxonomic notes. *New Zealand Journal of Botany* 43: 563–596.

de Lange PJ, Rolfe JR, Champion PD, Courtney SP, Heenan PB, Barkla JW, Cameron EK, Norton DA, Hitchmough RA (2013) *Conservation status of New Zealand indigenous vascular plants, 2012. New Zealand Threat Classification Series 3*. Department of Conservation, Wellington.

de Lange PJ, Beever JE (2015) A checklist of the mosses of the Kermadec Islands. *Auckland Museum Bulletin* 20: 183–205.

de Lange PJ, Galloway DJ (2015) Lichen notes from Raoul Island, Kermadecs Islands Group. I. Lobariaceae. *Auckland Museum Bulletin* 20: 115–137.

Engel JJ, Smith Merrill GL (1999) Austral Hepaticae 31. Two new species of *Plagiochila* (Dum.) Dum. (Plagiochilaceae) from New Zealand. *Journal of the Hattori Botanical Laboratory* 87: 295–300.

Engel JJ, Smith-Merrill GL (2010) Studies on New Zealand Hepaticae. 39–55. More new taxa, combinations, typifications and synonymy in *Plagiochila* from New Zealand (Plagiochilaceae). *Nova Hedwigia* 91: 501–517. DOI

Gentry S (2013) *Raoul and the Kermadecs – New Zealand's northernmost islands*. Steele Roberts Publishers, Wellington. 356 pp.

Hattori S (1979a) A revision of the Australasian species of the genus *Frullania,* Hepaticae, I. *Journal of the Hattori Botanical Laboratory* 45: 323–363. DOI

Hattori S (1979b) A revision of the Australasian species of the genus *Frullania,* Hepaticae, II *Journal of the Hattori Botanical Laboratory* 46: 119–153. DOI

Hattori S (1983) A revision of the Australasian species of the genus *Frullania,* Hepaticae, III *Journal of the Hattori Botanical Laboratory* 54: 133–182. DOI

Iredale T (1910) Birdlife on the Kermadec Islands. *Emu* 10: 2–16.

Iredale T (1913) Concerning the Kermadec Islands avifauna. *Transactions of the New Zealand Institute* 45: 215.

Iredale T (1914) The surface breeding petrels of the Kermadec Group. *Ibis* 2: 423–436.

Lloyd EF, Nathan S (1981) Geology and tephrochronology of Raoul Island, Kermadec Group, New Zealand. *New Zealand Geological Survey Bulletin* 95.

Merton DV (1970) Kermadec Islands expedition reports: a general account of birdlife. *Notornis* 17: 147–199.

Morton EK (1957) *Crusoe's of Sunday Island*. G.Bell and Sons Ltd, London.

Oliver WRB (1912) The geographic relationships of the birds of Lord Howe, Norfolk, and the Kermadec Islands. *Transactions of the New Zealand Institute* 44: 214–221. URL

Parkes JP (1984) Feral goats on Raoul. II. Diet and notes on Flora. *New Zealand Journal of Ecology* 7: 95–101.

Perrie LR, Brownsey PJ (2012) *Lastreopsis kermadecensis*, a new fern species from Raoul Island in the Kermadec Islands, New Zealand, with notes on *L. pacifica*. *New Zealand Journal of Botany* 50: 29–36.

Pócs T, Renner MAM (2021) Contribution to the bryoflora of Australia, V. *Radula tonitrua* sp. nov. from Queensland. *Telopea* 24: 189–201. DOI

Renner MAM (2005) Additions to the *Radula* (Radulaceae: Hepaticae) floras of New Zealand and Tasmania. *Journal of the Hattori Botanical Laboratory* 97: 39–79.

Renner MAM (2014) *Radula* subg. *Radula* in Australasia and the Pacific (Jungermanniopsida). *Telopea* 17: 107–167. DOI

Renner MAM (2018) A revision of Australian *Plagiochila* (Lophocoleinae: Jungermanniopsida). *Telopea* 21: 187–380. DOI

Renner MAM, Cargill DC, Meagher D, Karunajeewa N, Franks A, Klazenga N (2024) Updated checklist of Australian hornworts and liverworts. *Telopea* 28: In press. DOI

Renner MAM, de Lange PJ (2011) Additions to the Lejeuneaceae flora of New Zealand: new species from the Kermadec Islands and range extensions of New Zealand species into the South Pacific. *New Zealand Journal of Botany* 49: 421–433.

Renner MAM, Devos N, Brown EA, von Konrat MJ (2013) A revision of Australian species of *Radula* subg. *Odontoradula*. *Australian Systematic Botany* 26: 408–447. DOI

Revell CG (1981) Tropical cyclones in the southwest Pacific (1969 to April 1979). *Miscellaneous Publications* 170. Meteorological Service. Wellington, New Zealand. 55 pp.

So ML (2001) Recognised species of *Plagiochila* in Australasia and some island groups of the Pacific Ocean. *New Zealand Journal of Botany* 39: 395–421.

Söderström L, Hagborg A, von Konrat MJ, Bartholomew-Began S, Bell D, Briscoe L, Brown EA, Cargill DC, Costa DP, Crandall-Stotler BJ, Cooper ED, Dauphin G, Engel JJ, Feldberg K, Glenny DS, Gradstein SR, He XL, Heinrichs J, Hentschel J, Ilkiu-Borges AL, Katagiri T, Konstantinova, Larraín J, Long DG, Nebel M, Pócs T, Puche F, Reinder-Drehwald E, Renner MAM, Sass-Gyarmati A, Schäfer-Verwimp A, Moragues JGS, Stotler RE, Sukkharak P, Thiers BM, Uribe J, Vana J, Villarreal JC, Wigginton M, Zhang L, Zhu RL (2016) World checklist of hornworts and liverworts. *PhytoKeys* 59: 1–828. DOI

Sorenson JH (1964) Birds of the Kermadec Islands. *Notornis* 11: 69–81.

Stotler RE, Long DG (2009) Phylogeny and classification of the Marchantiophyta. *Edinburgh Journal of Botany* 66: 155–198.

Straubel CR (1954) The whaling journal of Captain W.B. Rhodes 1836–38. Whitcombe & Tombes. Christchurch. 122 pp.

Sykes WR (1969) The effects of goats on the vegetation of the Kermadec Islands. *Proceedings of the New Zealand Ecological Society* 16: 13–16.

Sykes WR (1971) *Senecio lautus* in the Kermadec Islands. *New Zealand Journal of Botany* 9: 533–538.

Sykes WR (1977) Kermadec Islands flora. An annotated checklist. With appendix: Hepaticopsida (Hepaticae) & Anthocerotopsida by Ella O. Campbell. *New Zealand Department of Scientific and Industrial Research Bulletin* 219: 1–199.

Sykes WR, West CJ (1996) New records and other information on the vascular flora of the Kermadec Islands. *New Zealand Journal of Botany* 34: 447–462.

Terry JP (2007) *Tropical cyclones: climatology and impacts in the south Pacific*. Springer, New York. 212 pp.

Thiers B (2018) Index Herbariorum: A global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. URL [12 June 2018].

Thiers B, Gradstein SR (1989) Lejeuneaceae (Hepaticae) of Australia. I. Subfamily Ptychanthoideae. *Memoirs of the New York Botanical Garden* 52: 1–79.

Trnksi T, de Lange PJ (2015) Introduction to the Kermadec Biodiversity Expedition 2011. *Bulletin of the Auckland Museum* 20: 1–18.

von Konrat MJ, Braggins JE (2001) Notes on five *Frullania* species from Australia, including typification, synonyms, and new localities. *Journal of the Hattori Botanical Laboratory* 91: 229–263. DOI

von Konrat MJ, Braggins JE (2003) A new and unusual species of *Frullania* (Jubulaceae) from Tasmania, Australia. *New Zealand Journal of Botany* 41: 55–62. DOI

Wardle P (1991) *Vegetation of New Zealand*. Cambridge University Press, Cambridge. 672 pp.

Wilmot-Dear CM, Friss I (2006) The old world species of *Pouzolzia* (Urticaceae, tribus Boehmerieae). *Nordic Journal of Botany* 24: 1–115. DOI

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Molecular phylogeny of the suspended aquatic *Utricularia* (sect. *Utricularia*) with a new hybrid species *U.* × *jacobsii* from northern Australia, a new section *Biovularia*, and confirmation of two species in New Zealand

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Abstract

Utricularia sect. *Utricularia* contains 36 recognised species world-wide, including the recently described *U. adamsii* from northern Australia. We here present a molecular phylogeny of subgenus *Utricularia* representing most Australian species based on sequences of two plastid markers and nuclear ITS. We provide molecular evidence for hybridization events between *U. aurea* and *U. muelleri* that have occurred sporadically across northern Australia. We found phylogenetic discordance between the plastid and nuclear sequences for two of the suspected hybrid specimens. The morphological differences between *U. muelleri*, *U. aurea* and the hybrid taxon are discussed with a formal description of the hybrid taxon presented as *Utricularia* × *jacobsii* R.W.Jobson & Baleeiro. We also provide molecular evidence for the introduction/naturalization of northeastern USA/Canada endemic *U. geminiscapa* into New Zealand (NZ) and confirm that a NZ accession of *U. australis* is most closely related to those *U. australis* populations distributed in south-eastern Australia. We expand the section *Avesicaria* to include the taxa in sections *Setiscapella* and *Steyermarkia*. Lastly, we recognise a new sectional name *Biovularia* (Kamieński) Baleeiro & R.W.Jobson for *U. olivacea* that was found to be excluded from sect. *Utricularia* and instead is supported as a close ally to sect. *Vesiculina*.

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Introduction

Recent progress has been made in understanding phylogenetic relationships across the recognised species of *Utricularia* L. (Lentibulariaceae Rich.) occurring in Australia (Jobson *et al*. 2017; Jobson & Baleeiro 2020, 2022, 2023; Jobson & Davies-Colley 2020) resulting in an increase from the 57 Australian species recognised by Taylor (1989) to 86. Recent work in Europe has made progress in understand the relationships between Eurasian species (Astuti *et al*. 2020; Bobrov *et al*. 2022), and although phylogenetic studies are progressing in the United States and Asia, this is limited to just one or a few samples from each region (Krishnapriya *et al*. 2024; Tippery *et al*. 2024). There has been extensive work by Baleeiro *et al*. (2016, 2019, 2022) on the *U. amethystina* Salzm. ex A.St.Hil. complex where representative distributions were sampled from across Central and South America. However, apart from that significant work, the situation in the Neotropics and Africa has not progressed significantly since the early phylogenetic work on the genus (Jobson & Albert 2002; Jobson *et al*. 2003; Muller *et al*. 2004), with many of the recognised endemic species yet to be sampled for phylogenetic study.

Utricularia section *Utricularia* contains 34 species (Taylor 1989) with a world-wide distribution and is nested within subgenus *Utricularia* (Muller & Borsch 2005). Taylor

(1989) recognised four species from the section in Australia with the recent description of the northern Australian species *U. corneliana* R.W.Jobson and *U. adamsii* R.W.Jobson & Davies-Colley increasing that number to six, and worldwide to 36 (Taylor 1989; Jobson 2013; Jobson & Davies-Colley 2020).

We present a molecular phylogeny for section *Utricularia* representing 25 of the 36 species, including most Australian taxa. We also include previously sampled representatives of sister clades including sections *Avesicaria* Kamieński, *Lecticula* (Barnhart) Komiya, *Nelipus* (Raf.) P.Taylor, *Setiscapella* (Barnhart) P.Taylor, *Steyermarkia* P.Taylor, and *Vesiculina* (Raf.) P.Taylor. Topological comparison of the plastid non-coding and nuclear ribosomal ITS trees provided molecular evidence of phylogenetic discordance between the sequences representing two suspected hybrid specimens. The two suspected hybridization events occurred between *U. aurea* and *U. muelleri* in northern Australia (as suspected by Taylor 1989). The morphological similarities between *U. muelleri*, *U. aurea* and the hybrid taxon are discussed. We also provide a formal description of *U.* x *jacobsii* R.W.Jobson & Baleeiro to allay confusion in the field and aid in biodiversity management. We provide molecular evidence for the introduction/naturalization of USA endemic *U. geminiscapa* Benj. into New Zealand (NZ) (Salmon 2001; Heenan *et al*. 2004; Champion & Hofstra 2024). We also provide molecular evidence of the presence of *U. australis* on the north island of NZ (Taylor 1989) and find it is most closely related to those populations distributed in south-eastern Australia.

As observed in Jobson *et al*. (2003) we find that *U.* sect. *Setiscapella* is paraphyletic and expand *U.* sect. *Avesicaria* Kamieński ex Prantl to accommodate the species from *U.* sect. *Setiscapella* (Barnhart) P.Taylor and *U.* sect. *Steyermarkia* P.Taylor. Lastly, our data supports two previous phylogenetic studies that each used different *U. olivacea* C.Wright ex Griseb. samples and found it is excluded from sect. *Utricularia* and is supported as a close ally to sect. *Vesiculina* (Jobson *et al*. 2003; Silva *et al*. 2023). To accommodate these results, we recognise the new section *Biovularia* (Kamieński) Baleeiro & R.W.Jobson for *U. olivacea*.

Methods and Materials

Taxon sampling and DNA extraction

DNA isolations were performed as for Jobson *et al*. (2017) with all ingroup and outgroup samples shown in table 1 of Jobson & Davies-Colley (2020) used in the current study. We obtained previously published sequences from GenBank that were published in Jobson & Albert (2002) and where samples were sourced from other studies, the GenBank number was included in the accession label (Figs 1, 2). Newly sampled accessions for *rps16* (n = 26), *trnD-T* (n=19), and ITS (n=19) were obtained from silica dried and herbarium sheet material and are listed in Table 1 of this study along with their relevant GenBank numbers for each sequenced marker. We expanded the plastid *rps16*/*trnD-T* (cpDNA) dataset to include ingroup sequences from sections *Avesicaria*, *Nelipus*, *Setiscapella*, and *Vesiculina* with most of these being previously published and presented in table 1 of Jobson & Albert (2002) (Fig. 1). The nuclear ITS dataset was restricted to ingroup accessions representing sect. *Utricularia* with most previously published in table 1 of Jobson & Davies-Colley (2020) (Table 1; Fig. 2).

Amplification and sequencing

Amplifications were performed as for Jobson *et al*. (2020) using two noncoding plastid (cpDNA) and nuclear ribosomal Internal Transcribed Spacer (ITS) region (nuDNA). The cpDNA markers included the *rps*16 intron amplified according to the program described in Oxelman *et al*. (1997), while the *trnD-trnT* intron spacer (*trnD-T*) (Demesure *et al*. 1995) was amplified using parameters described in Shaw *et al*. (2005). The ITS region was amplified using universal primers described in White *et al*. (1990) and Stanford *et al*. (2000). Forward and reverse sequences were assembled, edited and aligned as for Jobson *et al*. (2017).

Phylogenetic analyses

Topologies obtained from individual *rps16* and *trnD-T* analyses were congruent and were concatenated and analysed together. Separate phylogenetic analyses were performed on the combined *rps16/trnD-T* (cpDNA) and nuclear ITS matrices. For the Bayesian phylogenetic analyses, a suitable nucleotide substitution model was chosen for each of the datasets using the Akaike information criterion (AIC) implemented in the program jModelTest, ver. 2.1.7 (Guindon & Gascuel 2003; Posada 2008). We found that the best fit model was GTR + I + G and GTR + G for each the cpDNA and ITS datasets respectively. All other analyses were performed under the same parameters as described in Jobson & Davies-Colley (2020).

Results

Sequences and alignment

The *rps16* matrix was 1012 bp long of which 297 (29.3%) characters were parsimony informative, *trnD-T* matrix was 1422 long of which 250 (17.5%) characters were parsimony informative (Fig. 1), and the ITS matrix was 947 bp long of which 345 (36.4%) characters were parsimony informative (Fig. 2). An examination of the topologies showed the same branching order across both trees for all corresponding accession except those found to be of hybrid origin. Due this known incongruence (see also Jobson & Davies-Colley 2020), the cpDNA and nuDNA datasets were analysed separately (Figs 1, 2).

Phylogenetic relationships

The cpDNA tree (Fig. 1) corresponds with that of Jobson *et al*. (2003) with accessions representing section *Nelipus* maximally supported (posterior probability (PP) = 1.00) as sister to a clade containing sections *Avesicaria*, a paraphyletic *Setiscapella*, and *Steyermarkia*. Together the clade is sister to a maximally supported clade containing sect. *Vesiculina* which is sister to two accessions of *U. olivacea* of sect. *Utricularia* (Fig. 1). Sister to the above clade, sect. *Lecticula* is sister to a weakly supported sect. *Utricularia* that is supported here to be polyphyletic given the above-mentioned position of *U. olivacea* (Fig. 1). Within sect. *Utricularia* both the cpDNA and ITS trees show a similar branching order with a maximally supported monophyletic clade of *U. gibba* sister to *U. striata* and *U. floridana* (Figs 1, 2). Neither cpDNA nor ITS analyses were able to fully resolve relationships among the two major groups sister to the *U. gibba* clade. The first group involves the African accessions of *U. reflexa* and *U. benjaminiana* (also in the Neotropics) sister to a clade of Afrotropical/Asian and Australasia *U. inflexa*/*U. stellaris* that together were sister to a maximally supported Asian/Australasia group including *U. aurea*

+ *U. muelleri*/*U. adamsii* (Figs 1, 2). All members of the group except *U. reflexa* possess inflorescence flotation organs (Taylor 1989). We observed incongruence between the cpDNA and ITS topologies (Figs 1, 2) with two accessions *Jobson 2784*, and *Jobson 3588*, placed within the *U. aurea* and *U. muelleri* clades respectively in the cpDNA tree, while the opposite was the case in the nuclear tree, suggesting different sexual parents for each of these two hybrids (compare Figs 1, 2).

Table 1. Accessions used in the cpDNA and ITS matrices. Secondary collectors are not included. Locality abbreviations: NSW, New South Wales; NT, Northern Territory; Qld, Queensland; SA, South Australia; WA, Western Australia. GenBank accession numbers for each sequence are shown. NS indicates a sequence that either failed or was not included in the study. Information for previously published sequences provided in Jobson & Albert (2002), and Jobson & Davies-Colley (2020).

Section	Taxon	Collector	Location	ITS	*RPS16*	*trnDT*
Utricularia	*U. australis R.Br.*	R.W. Jobson 1369 (NSW)	Trebon, Czech Republic (ex. L. Adamec)	PQ130292	PQ129439	PQ129465
	U. australis R.Br.	R.W. Jobson 1617 (NSW)	Nangwarry, SA	PQ130293	PQ129440	NS
	U. australis R.Br.	R.W. Jobson 1591 (NSW)	Cape Le Grand National Park, WA	PQ130294	PQ129441	NS
	U. australis R.Br.	R.W. Jobson 1580 (NSW)	Cape Le Grand National Park, WA	PQ130295	NS	NS
	U. australis R.Br.	P.B. Heenan s.n. (CHR)	North Island, NZ	PQ130296	NS	NS
	U. australis R.Br.	R.W. Jobson 2270 (NSW)	Mitchell Falls, Kimberley, WA	PQ130297	NS	NS
	U. australis R.Br.	R.W. Jobson UQ184B (NSW)	Trebon, Czech Republic (ex. L. Adamec)	PQ130298	PQ129442	NS
	U. australis R.Br.	R.W. Jobson 3348 (NSW)	Apsley River, Tas.	PQ130303	NS	NS
	U. australis R.Br.	R.W. Jobson 1064 (NSW)	Sale, Vic.	PQ130286	NS	NS
	U. australis R.Br.	R.W. Jobson 1106 (NSW)	Myall Lakes, NSW	PQ130287	NS	NS
	U. australis R.Br.	R.W. Jobson 1168 (NSW)	Corduroy, NSW	PQ130288	NS	NS
	U. australis R.Br.	R.W. Jobson 1233 (NSW)	Richmond, NSW	PQ130289	NS	NS
	U. bremii Heer ex Kölliker	R.W. Jobson 1418 (NSW)	Trebon, Czech Republic (ex. L. Adamec)	NS	PQ129443	PQ129466
	U. breviscapa Wright ex Griseb.	R.W. Jobson 1420 (NSW)	Brazil (ex. L. Adamec)	NS	PQ129444	PQ129467
	U. floridana Nash	R.W. Jobson 1368 (NSW)	USA (ex. L. Adamec)	NS	PQ129445	PQ129468
	U. foliosa L.	R.W. Jobson 1421 (NSW)	Cuba (ex. L. Adamec)	NS	PQ129446	PQ129469
	U. geminiscapa Benj.	P. Champion 125 (CHR)	Westland District, NZ	PQ130290	NS	PQ129482
	U. gibba L.	R.W. Jobson 1362 (NSW)	Bundeena, NSW	NS	PQ129447	PQ129470
	U. gibba L.	R.W. Jobson 1380 (NSW)	Mt Garnet, Qld	NS	NS	PQ129471
	U. gibba L.	R.W. Jobson 2250 (NSW)	Humpty Doo, NT	NS	NS	PQ129472
	U. gibba L.	R.W. Jobson 2321 (NSW)	Dampier Penninsula, WA	NS	NS	PQ129473
	U. gibba L.	F. Rivadavia 974 (SPF)	Minas Gerais, Brazil	NS	PQ129448	NS
	U. gibba L.	R.W. Jobson 1373 (NSW)	Florida, USA (ex. L. Adamec)	NS	PQ129458	PQ129477
	U. gibba L.	R.W. Jobson 2632 (NSW)	Elizabeth Springs, Qld	NS	NS	PQ129481
	U. hydrocarpa Vahl	R.W. Jobson 1424 (NSW)	Brazil (ex. L. Adamec)	PQ130299	PQ129449	PQ129474
	U. hydrocarpa Vahl	P.C. Baleeiro 329 (SPF)	Rio De Janeiro, Brazil	NS	PQ129450	NS
	U. hydrocarpa Vahl	F. Rivadavia 1029 (SPF)	Goias, Brazil	NS	PQ129451	NS
	U. inflata Walter	R. Haynes 10211 (UNA)	Autauga Co., Alabama, USA	PQ130300	PQ129452	NS
	U. intermedia Hayne	R.W. Jobson UQ185 (NSW)	Trebon, Czech Republic (ex. L. Adamec)	NS	PQ129453	NS
	U. macrorhiza LeConte	J. Ricketson 4425 (NY)	Coconino Co., Arizona, USA	NS	PQ129454	PQ129475
	U. minor L.	R.W. Jobson 1419 (NSW)	Trebon, Czech Republic (ex. L. Adamec)	NS	PQ129455	PQ129476
	U. muelleri Kamiénski	R.W. Jobson 4020 (NSW)	Jabiru, NT	PQ130291	PQ129464	PQ129483
	U. ochroleuca R.Hartm.	R.W. Jobson 1371 (NSW)	Trebon, Czech Republic (ex. L. Adamec)	NS	PQ129456	NS
	U. ochroleuca R.Hartm.	R.W. Jobson UQ186 (NSW)	Trebon, Czech Republic (ex. L. Adamec)	NS	PQ129457	NS
	U. radiata Small	B. Hellquist 17370 (MCLA)	USA (ex. B. Hellquist)	PQ130301	NS	PQ129478
	U. reflexa Oliver	R.W. Jobson 1423 (NSW)	Zambia (ex. L. Adamec)	PQ130302	PQ129459	PQ129479
	U. warmingii Kamiénski	P. Cardoza 131 (SPF)	Pantanel, Brazil	NS	PQ129462	PQ129480
	U. stygia Thor	R.W. Jobson 1422 (NSW)	Trebon, Czech Republic (ex. L. Adamec)	NS	PQ129460	NS
Setiscapella	*U. subulata* L.	D. Murfet 6118 (DNA)	Sanamere Lagoon, Qld	NS	PQ129463	NS
Steyermarkia	*U. steyermarkii* P.Taylor	P.C. Baleeiro 333 (NSW)	Mato Grosso, Brazil	NS	PQ129461	NS

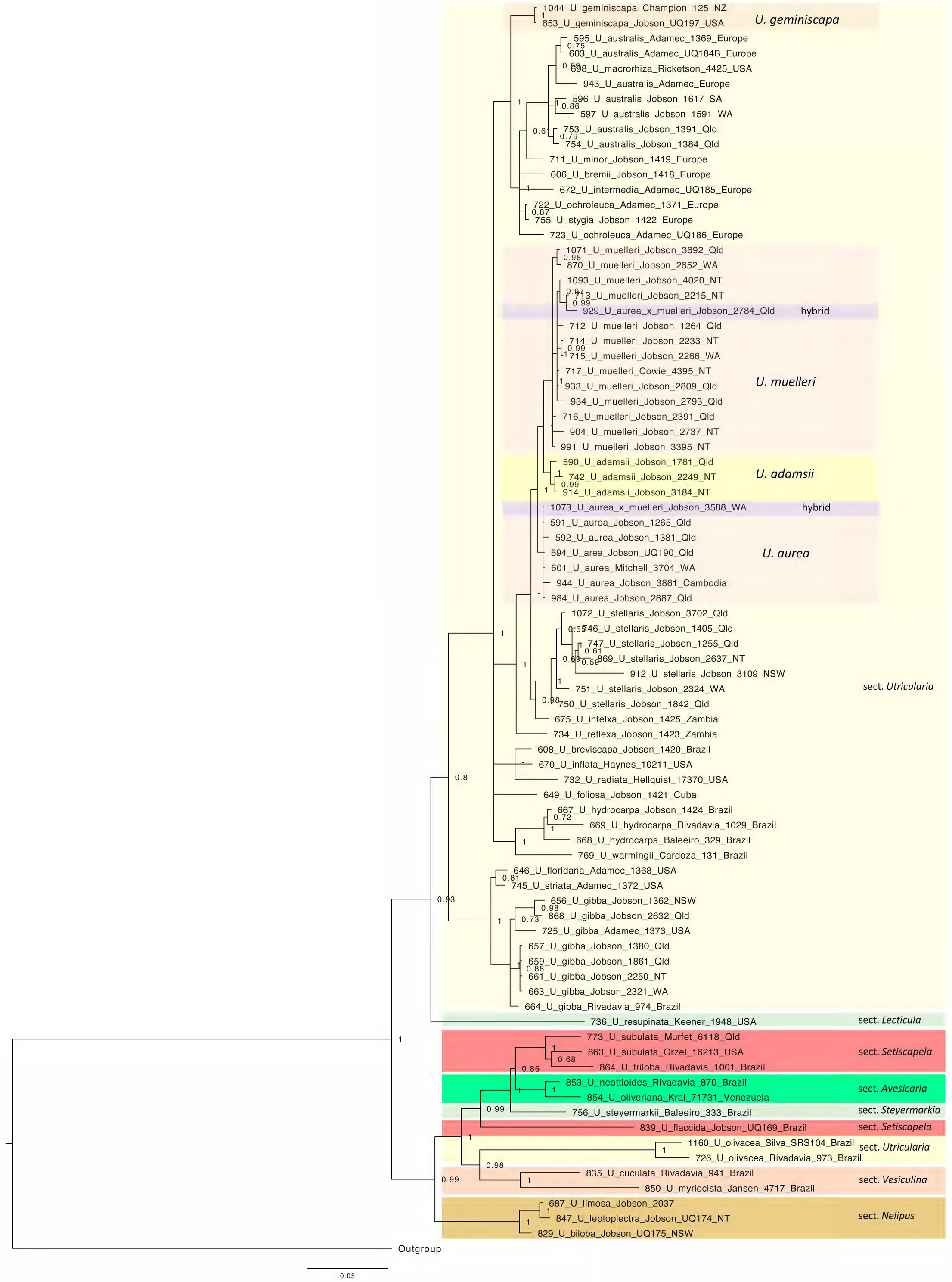

Figure 1. 50% majority-rule Bayesian inference consensus tree for concatenated cpDNA data set; Posterior probability (PP) support values are shown above branches. PP = 1.0–0.95: strong support; 0.94–0.84: weak support; <0.84: not supported. Shaded boxes coloured according to section. Hybrid accessions indicated by purple shading, Accessions of *U. geminiscapa* shown with orange shading.

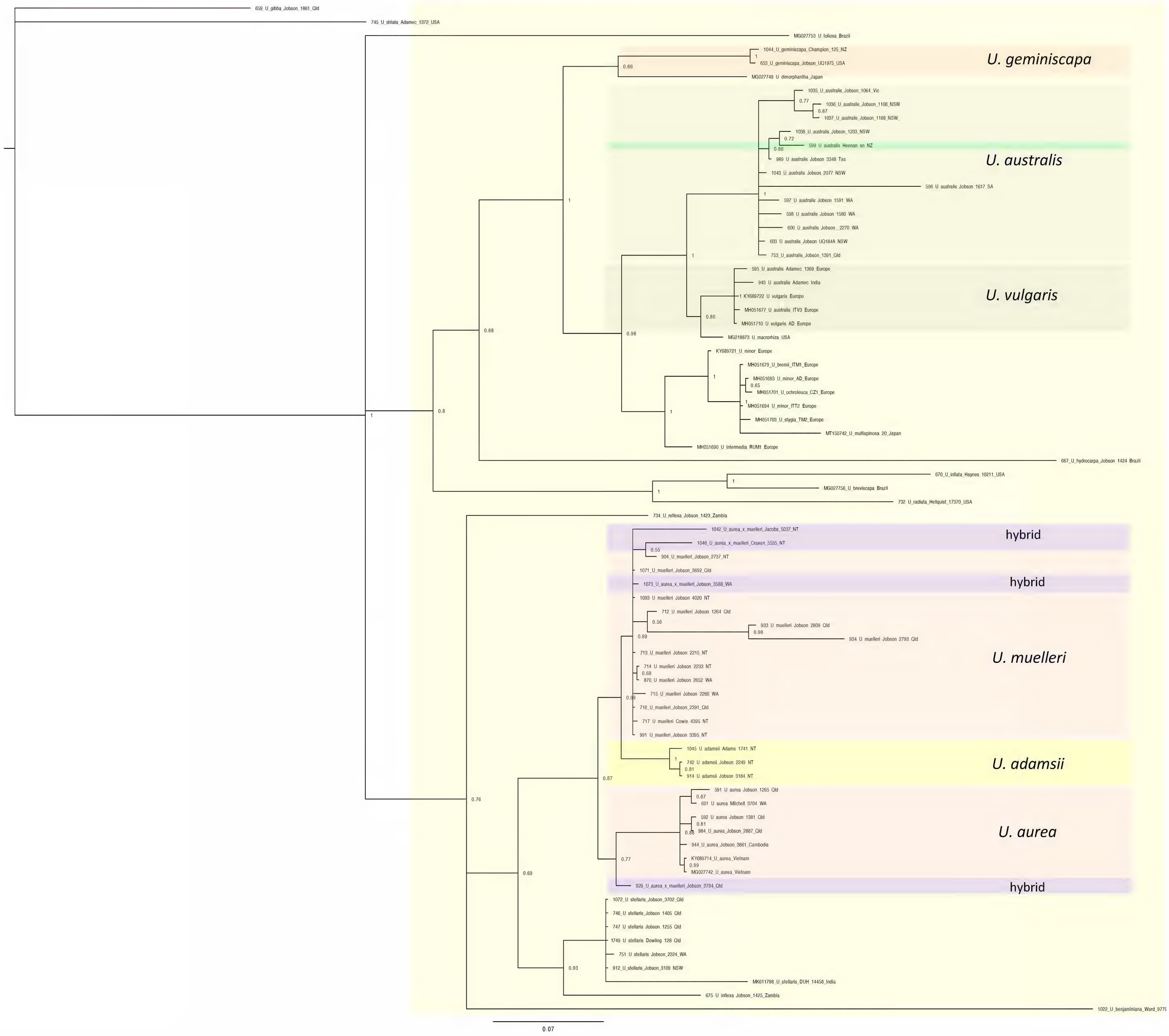

Figure 2. 50% majority-rule Bayesian inference consensus tree for ITS data set; Posterior probability (PP) support values are shown above branches. PP = 1.0–0.95: strong support; 0.94–0.84: weak support; <0.84: not supported. Shaded boxes coloured according to section. Hybrid accession indicated by purple shading, New Zealand accession of *U. australis* and *U. geminiscapa* shown with green and orange shading respectively.

A single representative of the Afrotropical/Neotropical and morphologically distinct *U. foliosa* is unresolved in both cpDNA and ITS trees and may form a third clade along with other currently unsampled species (Figs 1, 2). The second major grouping involves mainly Palaearctic/Nearctic species with *U. breviscapa* and *U. hydrocarpa* extending into the Neotropics, and *U. australis* into most realms except the Afro-tropic/Neotropics, although this group is mostly unresolved in the cpDNA tree (Fig. 1).

The ITS tree provides maximally supported resolution showing the three species possessing inflorescence floats namely *U. breviscapa*/*U. inflata*/*U. radiata* (Fig. 2) sister to a maximally supported clade of mainly Palaearctic/Nearctic species with *U. australis* extending to Afro-tropics/Asia/ Australasia (Fig. 2). Both trees show the North American *U. geminiscapa* is sister to the *U. australis* group including *U. intermedia*/*U. bremii*-*U. vulgaris*-*U. macrorhiza*-*U. minor*-*U. ochroleuca*.

The ITS tree shows the Neotropical *U. hydrocarpa* sister to *U. geminiscapa*/*U. australis* + allies with the Japanese *U. dimorphantha* sister to *U. geminiscapa* (Fig. 2). Both trees show the New Zealand accession of *U. geminiscapa* is sister to an accession of that species from its natural North American range. In addition, a *U. australis* accession from the north Island of New Zealand is nested within a grouping of that species from south-eastern Australia (Fig. 2).

Discussion

Hybridization between U. aurea *and* U. muelleri

Two suspected hybrids of *Utricularia aurea* and *U. muelleri* were identified by Taylor (1989) under his description of *U. muelleri* involving collections by *Craven 5535* (CANB) and *Jacobs 1862* (NSW). These specimens appear to be sterile with no fruit development observed and possess an intermediate morphology with a suite of characters; similar floral features to *U. aurea*, while peduncle floats resembled those of *U. muelleri* (Figs 3, 4).

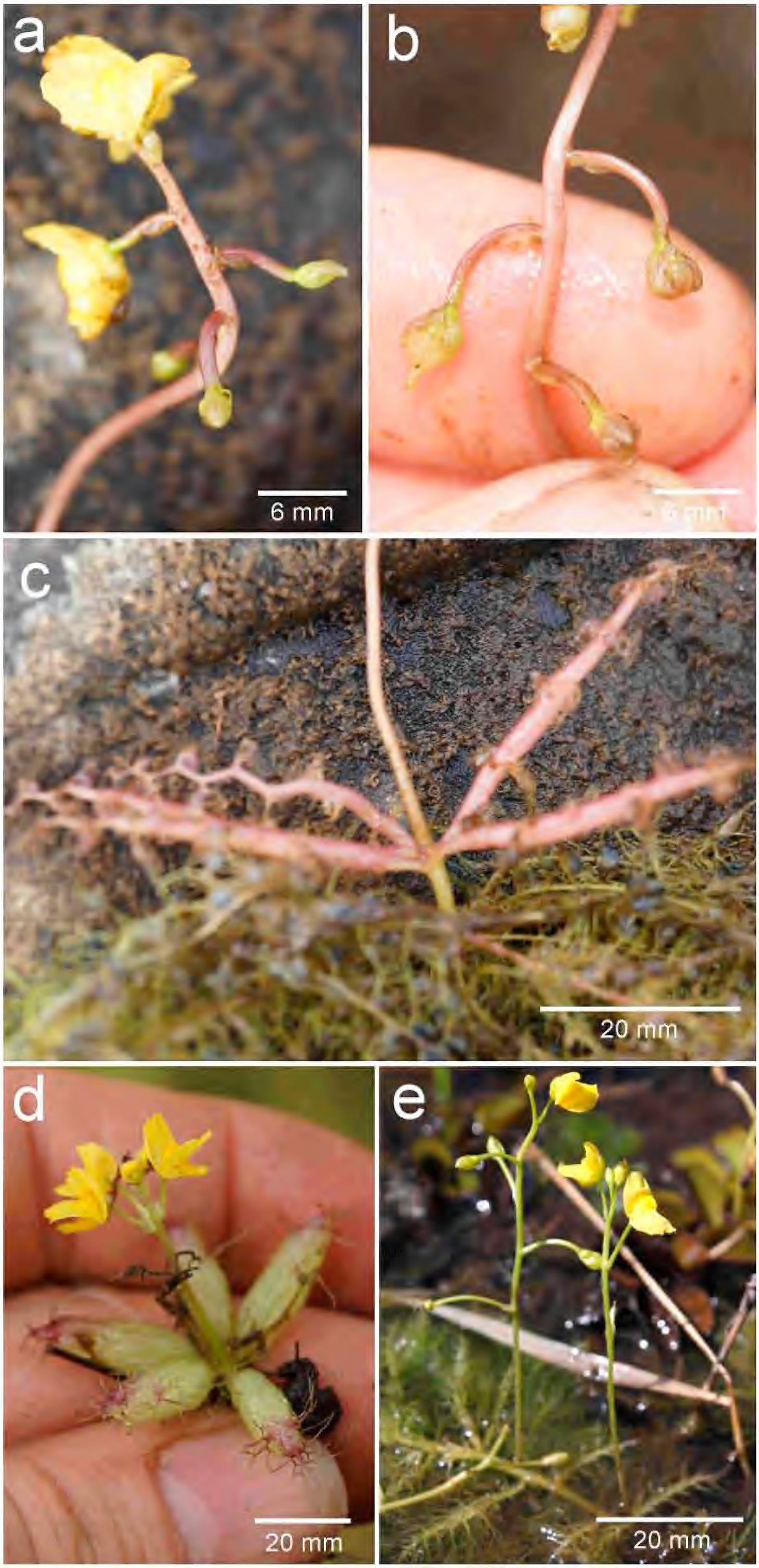

Figure 3. *Utricularia* × *jacobsii*: **a**, Inflorescence with flowers; **b**, immature seed capsules; **c**, habit showing floating organs towards the base of peduncle; **d**, *U. muelleri* showing inflorescence and attached floating organs; **e**, *U. aurea* habit showing primary stolon axis with erect inflorescences. Scale bars: a–c = 4 mm; c–e = 10 mm. Images: a–c = *Jobson 3588 & Baleeiro* (NSW 945185); d *Jobson 4157 & Baleeiro* (NSW 963030); & e = Glenn Leiper.

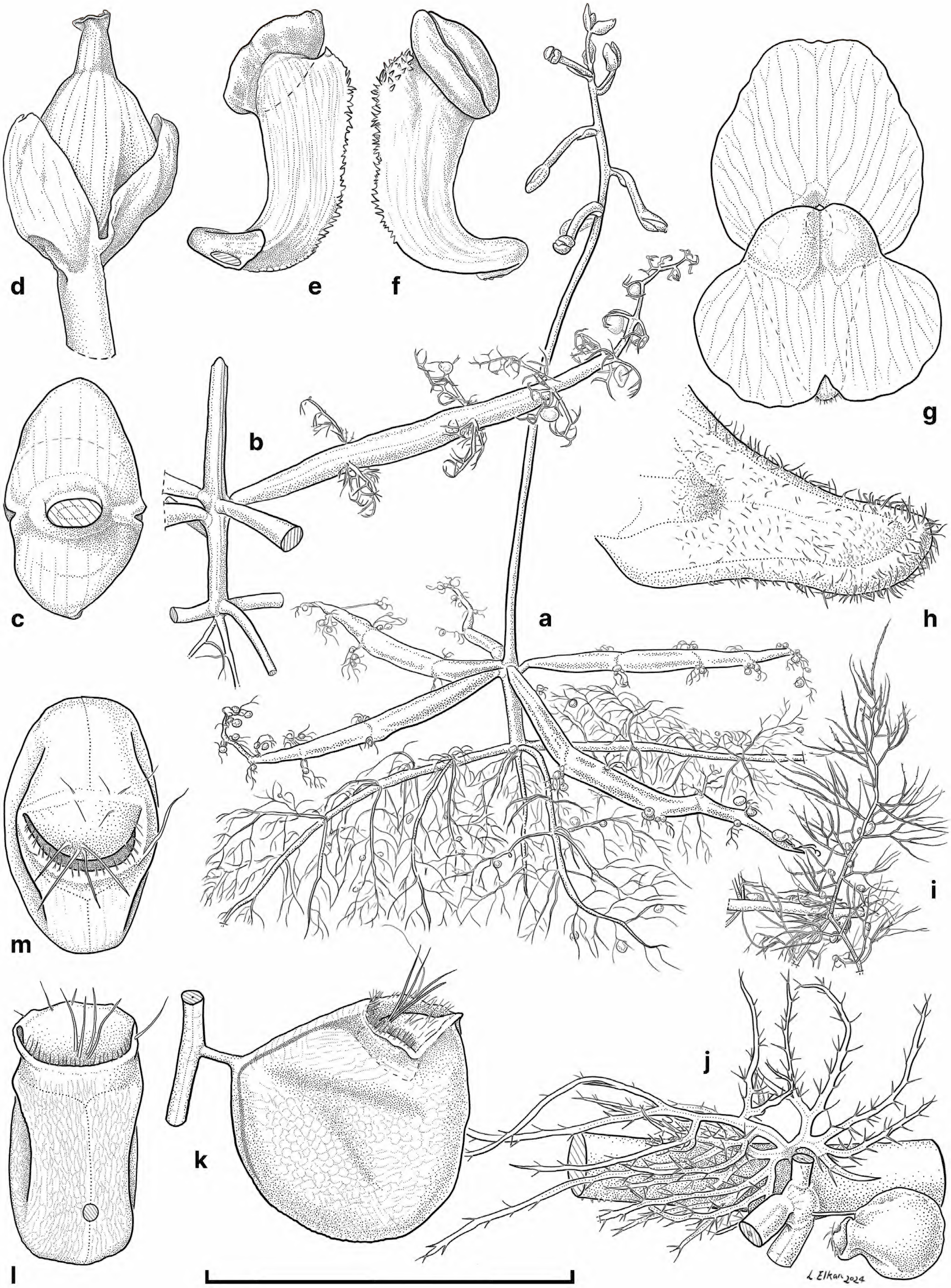

Figure 4. *Utricularia × jacobsii*. a. habit; b, peduncle float in situ; c, calyx dorsal view; d, immature capsule in situ; e, stamen dorsal view; f, stamen frontal view; g, corolla frontal view; h, corolla spur lateral view; i, leaf secondary segment; j, stolon node with leaf and bladder-trap in situ; k, bladder-trap lateral view; l, bladder-trap dorsal view; m, bladder-trap frontal view. Scale bar: a & i = 40 mm; c & d = 7.5 mm; e & f = 2.5 mm; h = 12 mm; j = 6 mm; k = 3 mm; l & m = 4 mm. Material used: *Jobson 3588 & Baleeiro* (NSW945185 - spirit). Illustration by L. Elkan.

Two more recent peduncle-float bearing collections of *U. aurea* from Cape York (*Jobson 2784*) and the Kimberley, WA (*Jobson 3588*) were used in this study to determine topological position in plastid and nuclear ITS trees (Figs 1, 2). We found that *Jobson 2784* was nested in *U. aurea* in the ITS phylogeny, while in the plastid phylogeny it is placed within the *U. muelleri* clade (compare Figs 1, 2). In the case of *Jobson 3588* we find the opposite situation where it was nested in *U. muelleri* in the ITS phylogeny, while nested with *U. muelleri* in the plastid tree (compare Figs 1, 2). This comparison was not possible for the *Craven (5535)* and *Jacobs (1862)* accessions due to the age and condition of the preserved specimens preventing amplification of usable chloroplast fragments for sequence assembly. However, the ITS sequences place both accessions within the *U. muelleri* clade (Fig. 2).

In comparison to *Craven 5535* and *Jacobs 1862*, *Jobson 2784* and *Jobson 3588* looked to be fertile, possessing several mature seed capsules. However, seed were found to be prismatic in shape like those of *U. aurea*, but otherwise malformed with no obvious testa cells (RWJ, pers. obs.). Likewise, pollen was found to be clumped with no obvious external structure (RWJ, pers. obs.). From these observations it is likely that hybrids form sporadically across northern Australia and the maternal taxon can involve either of the parent species.

Taxonomy

Utricularia × jacobsii R.W.Jobson & Baleeiro sp. nov.

Diagnosis: Inflorescence similar to *U. aurea* in possessing calyx lobes half as long as the capsule, and *U. muelleri* having floats positioned mid-way along the peduncle but differs from *U. muelleri* in the shape of its floats and the ad hoc positioning of floats in the whorl.

Type: Australia: Northern Territory: Darwin and Gulf: Near Jim Jim Creek, 6.5 km south-east of Cooinda. *L.A. Craven 5535*, 17 May 1980 (holo: DNA D0019326 – sheet!; iso: CANB 316054.1 – sheet!; CANB 316054.2 – spirit!).

Medium-sized perennial, suspended aquatic herb. *Rhizoids* few from base of peduncle, 10–15 mm long bearing short papillose branches. *Stolons* filiform, terete, 50–60 mm long, 0.9–1.2 mm thick, unbranched, hairy, internodes 6–11 mm long. *Leaves* numerous, 2 or 3 primary segments at each node, 25–35 mm long, slightly flattened, divided near the base into 2 or 3 primary segments, with few further dichotomously divided segments, laterally and apically setulose. *Traps* inserted along segments, shortly stalked, ovoid 2.0–3.1 mm long, mouth lateral with dorsal antennae absent or, two small setiform appendages c. 0.2 mm long. Internal glands 4-armed, each cylindrical arm ~same length, up to 130 µ long. *Inflorescence* erect, simple, emergent; peduncle filiform 50–150 mm long, 0.8–1.2 mm thick, terete, glabrous, with a ± whorl of 4 spongy floats, position near the middle of the peduncle, each float 30–40 mm long, c. 0.5 mm thick, sessile, cylindrical, zig-zag shaped towards the apex, bearing short leaf segments along the margin. *Scales* absent. *Bracts* basifixed, ovate when flattened, convex, 2.0–2.5 mm long, 1.2–1.5 mm wide, apex acute. *Bracteoles* absent. *Flowers* 5–10 on an elongated raceme axis; pedicels terete, thickening toward the apex, glabrous, erect or deflexed, 6.0–8.0 mm long, 0.5–0.7 mm thick. *Calyx* lobes subequal, gapping or adnate to ovary, each slightly glandular towards the apex, upper lobe broadly ovate slightly longer, 2.8–3.1 mm long, 0.9–1.1 mm wide, apex acute; lower lobe broadly ovate, 2.8–3.1 mm long, 0.6–1.1 mm in diam 2.6–2.8 mm long, 0.9–1.0 mm wide, apex rounded or emarginate. *Corolla* bright yellow, 9–10 mm long, with few very faint brownish-red nerves near the base of the upper lip; upper lip limb broadly ovate with apex rounded or truncate 6–7 mm long, 5.0–5.5 mm wide; lower lip limb transversely elliptic, 5.0–5.5 mm long, c. 6 mm wide, lower surface sparsely glandular, bilobed, with a prominent swelling at the base; spur glandular near apex, 4.0–4.2 mm long, c. 2 mm wide, equal length of lower lip, conical with rounded apex. *Filaments* curved c. 1.4 mm long, theca sub-distinct. *Ovary* globose. Immature capsules c. 3.1 mm long, c. 3.0 mm in diameter, walls fleshy, dehiscence unknown. *Seeds*, where produced (e.g., *Jobson 2784*) are prismatic but deformed – shaped unlike either parent. *Pollen* 14–17 colporate, 15 × 15 µ, often deformed (*Jobson 3588*), or all observed grains deformed (*Craven 5535* & *Jacobs 1862* sensu Taylor (1989)). **Figure 3a–c, 4**.

Additional probable hybrid specimens examined: AUSTRALIA: Northern Territory: Goomadeer Station, Goomadeer River, *S. Jacobs 1862*, 5 Jun 1974 (NSW 681749); East Alligator River crossing. *D.H. Benson 977*, 14 Jul 1974 (NSW 681750); Jabiluka billabong, Magela Ck. *S. Jacobs 5037, G. Sainty & K.L. Wilson*, 17 May 1987 (NSW 833516). Queensland: Cook: Crosbie Creek near Homestead, *R.W. Jobson 2784*, 15 July 2015 (NSW 922658). Western Australia: North Kimberley: Little Mertens Falls, *R.W. Jobson 3588 & P.C. Baleeiro*, 29 Apr 2019 (NSW 945185)

Etymology: The specific epithet honours the late Dr. Surrey Wilfrid Laurance Jacobs (1946–2009) who in June 1974 collected the first known specimen of *U. aurea* × *muelleri*. Surrey Jacobs worked as a systematic botanist at the National Herbarium of NSW at the Royal Botanic Gardens, Sydney. His major research efforts focussed on the systematics of water plants, grasses, chenopods, and weeds.

Distribution and ecology: Although this hybrid is only known from five collections (Fig. 5), it has been observed in several other locations where both parents *U. aurea* and *U. muelleri* occur (RWJ, pers. obs.). The collections were made on Cape York, Qld in a small lagoon (*Jobson 2784*), with *U. muelleri* and *Najas malesiana*. In the NT, one site was in a river system near Gunn Point east of Darwin (*Jacobs 1862*), and three sites in the region around Jabiru (*Jacobs 5037, Benson 977, Craven 5535*). A single collection was made from WA in a small pool above Little Mertens Falls, North Kimberley (*Jobson 3588*) growing with *U. australis*, *U. muelleri* and *Nymphaea violacea*.

Phenology: Flowers April–July. Functionally sterile.

Conservation status: Although *U. × jacobsii* is known from a wide distribution on Cape York, Qld, Top End, NT, and Kimberley region, WA, (Fig. 5) its density within any particular area is mostly unknown. From the few collections since *Jacobs 1862* (1974) it seems that its occurrence is rare. Future surveys are required to determine conservation status, and based on the available data, this species should be considered data deficient. As an apparently sterile hybrid, its presence in the landscape may be most reliant on repeated hybridisation events, though vegetative reproduction is entirely possible.

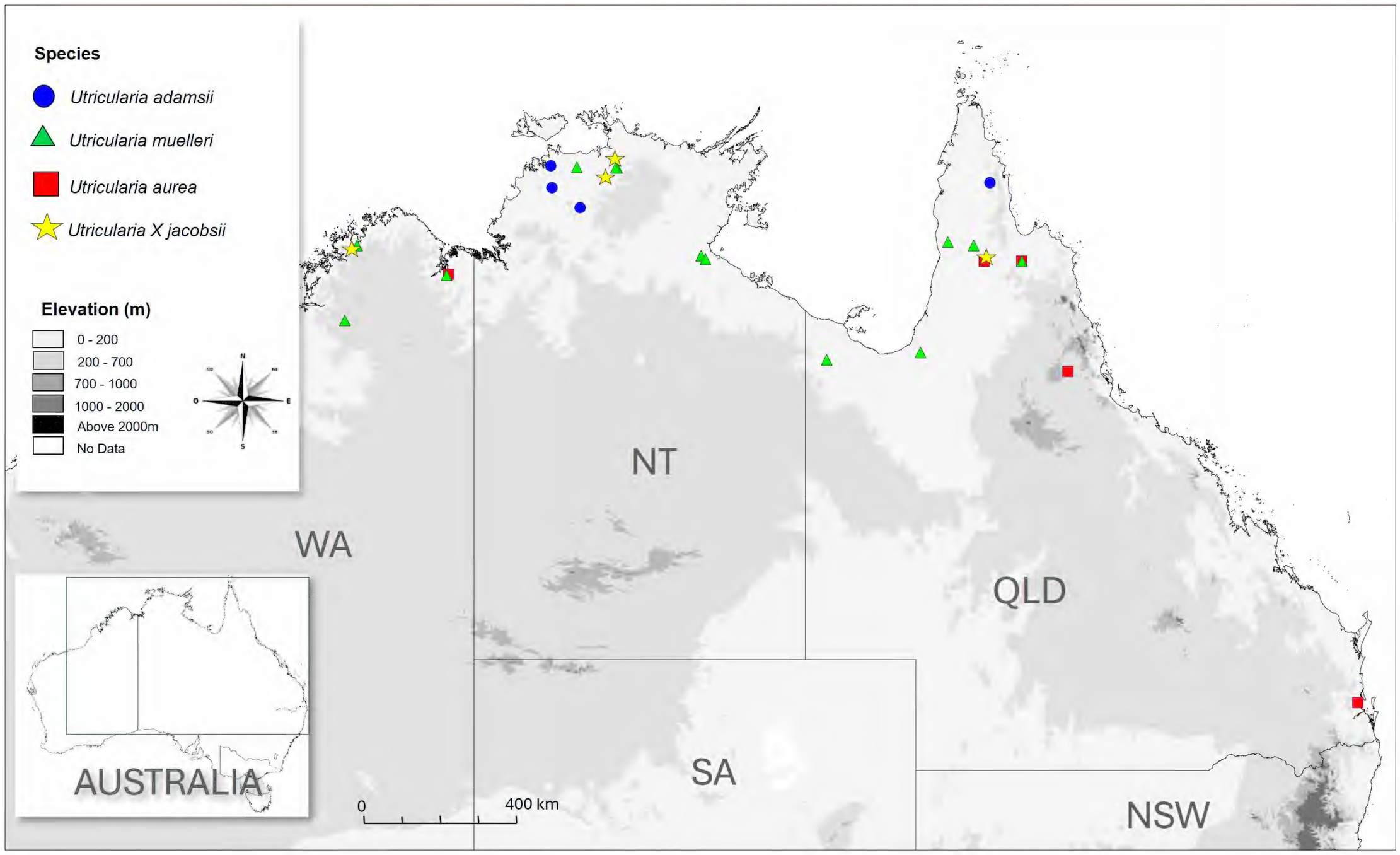

Figure 5. Distribution map showing accessions of *Utricularia muelleri* and allied species used in the current study: *Utricularia adamsii* (blue circle), *U. aurea* (red square), *U. muelleri* (green triangle), *U. × jacobsii* (yellow star).

Molecular evidence for the naturalisation of *U. geminiscapa* Benj., and presence of *U. australis* R.Br., in New Zealand

Utricularia geminiscapa is a perennial, suspended aquatic herb with a natural distribution across northeastern USA and Canada (Taylor 1989). The first collection of this species on the west coast of South Island, New Zealand (NZ) was in February 1975 (*Moar N.T & Mason R. 13126*; CHR 357934). On the North Island of NZ, the Eurasian/Australian *Utricularia australis* (syn = *U. protrusa*) occurs as a rare native species that is superficially morphologically similar and this name was originally applied to the NZ *U. geminiscapa* plants (Salmon 2001). Webb & Sykes (1997) examined the dorsiventrally compressed and rounded seed from the collection and found similarity to those of *U. geminiscapa* Benj. but not to those of the NZ populations of *U. australis*. Based on this evidence and in agreement with Moar & Mason (1975), Webb & Sykes (1997) re-instated *U. protrusa* Hook.f suggesting that the collection matched the type specimen. Salmon (2001) was first to realise that the *Moar N.T & Mason R. 13126* collection was not *U. protrusa* but instead was a cleistogamous form of *U. geminiscapa* that was likely introduced to NZ. Based on comparison of morphological characters such as internal bladder-trap glands, Heenan *et al.* (2004) provided a formal description of the *Moar N.T & Mason R. 13126* collection, along with several subsequent gatherings from the region, as *U. geminiscapa*, concluding that it is most likely recently naturalised.

Our study included an accession of a suspended aquatic taxon that was collected from a pool feeding into Dismal Creek near Waiatoto on the west coast of the South Island, New Zealand (*Champion 125*; CHR 608055A). This is one of several other gatherings of what appears to be the same taxon further north-west along the coast at Hokitika (225 km), and Westpoint (340 km). Our plastid phylogeny places *Champion 125* as sister to a previously sequenced collection from Bass River, New Jersey, USA (*R.W. Jobson 197*; BRI). The cpDNA representing *Champion 125* (used in this study Fig. 1), and an additional *trnL-F* sequence (not shown) were identical to those of the USA collection. Our ITS data includes an accession of the Japanese endemic species *U. dimorphantha* Makino of which the two *U. geminiscapa* accession are sister (Fig. 2). These results suggest the populations represented by *Champion 125* are likely very recent introductions to NZ. Further population genetic data may provide clues to timing and gene flow within and between NZ populations. Our ITS data also included a NZ sample of *U. australis* (*Heenan s.n.*, Table 1) and our analyses resolved it as sister to the south-eastern Australian accessions of that species, that together are sister to two monophyletic clades containing USA *U. macrorhiza* and European accessions of *U. australis*-*U. vulgaris* respectively (Fig. 2).

Proposal for changes to sectional circumscriptions

Following the results of Jobson *et al.* (2003) and those in Fig. 1, showing *U.* sect. *Setiscapella* (Barnhart) P.Taylor in Kew Bull. 41:15 (1986) as paraphyletic we propose that *Utricularia* sect. *Avesicaria* Kamieński ex Prantl in Nat. Pflanzenfam. 4(3b): 121 (1891) should be expanded to include the species in *U.* sect. *Setiscapella* and *U.* sect. *Steyermarkia* P.Taylor in Kew Bull., Addit. Ser. 14: 517–518 (1989). Our results show sect. *Setiscapella* paraphyletic with *U. flaccida* sister to a clade that includes taxa from sections *Setiscapella*, *Steyermarkia* and *Avesicaria* (Fig. 1).

Proposal for new section

Based on the polyphyletic position of sect. *Utricularia* relative to *U. olivacea* (Fig. 1) the latter has been assigned to the new section *Biovularia* (see below). A Brazilian accession of *U. olivacea* (*R.F. Rivadavia 937*, SPF) was fully supported as sister to sect. *Vesiculina* using plastid *rps16* and *trnL-F* (Jobson & Albert 2002; Jobson *et al*. 2003, 2018). Although another study using the plastid *matK* marker (Muller *et al*. 2004) placed the leafless *U. olivacea* near *U. gibba* (sect. *Utricularia*), the material used in that study was found to be a small-leaved form of *U. gibba* from southern USA (= *Adamec 1373*, this study; L. Adamec, pers. comm.; Jobson *et al*. 2018). In support of the Jobson *et al*. (2003) result, Silva *et al*. (2023) included a different Brazilian accession of *U. olivacea* (= *Silva SRS104* this study) in their full chloroplast *and* mitochondrial analysis and placed the accession sister to a single accession representing sect. *Vesiculina*. In this study, we have used the *rps16* and *trnD-T* introns (*Silva* SRS104) extracted from the plastid genome assembly used in the Silva *et al*. (2023) study in addition to those used previously representing *R.F. Rivadavia 937* (Jobson & Albert 2002; Jobson *et al*. 2003, 2018). A future study that includes accessions of the morphologically similar species *U. naviculata* and *U. biovularioides* will help further resolve relationships within this unusual group.

Figure 6. Lectotype of *U. olivacea* showing gathering of *Wright 2891* (GOET005729).

In the terrestrial/subaquatic sections *Nelipus* and *Setiscapella*, and suspended aquatic section *Vesiculina*, dehiscence is mostly from a single ventral longitudinal slit (Taylor 1989). Seeds are generally ovoid to globose in shape with varying forms of testa ornamentation, including multicellular outgrowths (Taylor 1989). In contrast, the seed capsule in the three species *U. biovularioides, U. naviculata* and *U. olivacea* is indehiscent; a situation where the seed/s are released upon breakdown of the capsule walls (Robins & Subramanyam 1980; Taylor 1989). These three species also share a lack of free-ending leaf segments (Beal & Quay 1968; Taylor 1989) and they differ from all other members of subgen. *Utricularia* in producing two to several ovules, and producing a single, 3–4 or 7 seed/s (Taylor 1989). A difference within the group is that *U. biovularioides* and *U. olivacea* have unwinged smooth-coated seeds while in *U. naviculata* the seeds have a marginal wing (Taylor 1989).

Utricularia section ***Biovularia*** (Kamieński) Baleeiro & R.W.Jobson, sect. et. stat. nov.

Basionym: *Biovularia* Kamieński, Zap. Novorossiisk. Obshch. Estestvoisp. 15: 205 (1890).

Type species: *Utricularia olivacea* C.Wright ex Griseb., here designated.

Illustration: Taylor (1989), fig. 211.

Herba aquatica, minuta. Folia alterna, capillariter partita, ascidiifera. Ascidia birostrata. Scapus esquamatus, bracteatus, 1–3-florus; bractea infirma ad caulem proxima; bracteae basifixae; bracteolae nullae. Calyx 2-lobatus; lobi subaequales. Corolla xanthica, hyalina, valde 2-labiata; labia integra; palatum tantum convexitas; calar saccatum. Antherae subglobosae. Ovarium 2-ovulatum. Capsula (achenium) globosa, 1-seminata, indehiscens.

Minute, suspended aquatic. Rhizoids and leaves absent. Stolon capillary bearing numerous traps. Traps ovoid with lateral mouth; long stalk and two long setiform appendages. Scales absent, bracts basifixed, bracteoles absent. Inflorescence bearing 2–5 flowers, apparently reduced or no peduncle. Sepals subequal, rounded, inferior slightly larger. Diminutive corolla creamy-white or white. Ovary ovoid with two ovules and producing one seed, indehiscent.

We here designate a lectotype for the type species of the section: *Utricularia olivacea* C.Wright ex Griseb., Cat. Pl. Cub. [Grisebach] 161 (1866). Lectotype (here designated): *Wright 2891*, (lecto: GH [GOET005729; Fig. 6]; isolecto: BM, G, K, LE, N, P, S, US, W, YU).

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References

Astuti G, Petroni G, Adamec L, Miranda VFO, Peruzzi L (2020) DNA barcoding approach fails to discriminate Central European bladderworts (*Utricularia*, Lentibulariaceae), but provides insights concerning their evolution. *Plant Biosystems* 154: 326–336. DOI

Baleeiro P, Jobson RW, Sano P (2016) Morphometric approach to address taxonomic problems: The case of *Utricularia* sect. *Foliosa* (Lentibulariaceae). *Journal of Systematics & Evolution* 54: 175–186. DOI

Baleeiro P, Sano P, Jobson RW (2019) Molecular phylogeny of the *Utricularia amethystina* complex (Sect. *Foliosa*) addressed using plastid and nuclear sequences data. *Systematic Botany* 2: 398–404. DOI

Baleeiro PC, Sano P, Gonella P, Jobson RW (2022) Unveiling the true colours of *Utricularia amethystina*: a taxonomic revision of *U.* sect. *Foliosa*, Lentibulariaceae. *Phytotaxa* 576: 29–54. DOI

Barnhart JH (1915) Segregation of genera in the Lentibulariaceae. *Memoirs of the New York Botanical Garden* 6: 39–64

Beal EO, Quay TL (1968) A review of *Utricularia olivacea* Wright ex Grisebach (Lentibulariaceae). *Journal of the Elisha Mitchell Scientific Society* 84: 462–466.

Bobrov AA, Volkova PA, Kopylov-Guskov YO, Mochalova OA, Kravchuk AE, Nekrasova DM (2022) Unknown sides of *Utricularia* (Lentibulariaceae) diversity in East Europe and North Asia or how hybridization explained old taxonomical puzzles. *Perspectives in Plant Ecology, Evolution and Systematics* 54: 1–19. DOI

Champion P, Hofstra D (20242). *Utricularia geminiscapa*. NIWA publication. URL

Guindon S, Gascuel O (2003) A simple, fast and accurate method to estimate large phylogenies by maximum likelihood. *Systematic Biology* 52: 696–704. DOI

Heenan PB, de Lange PJ, Knightsbridge PI (2004) *Utricularia geminiscapa* (Lentibulariaceae), a naturalised aquatic bladderwort in the South Island, New Zealand. *New Zealand Journal of Botany* 24: 247–251. DOI

Jobson RW (2012) *Utricularia corneliana* R.W.Jobson (Lentibulariaceae), a new species from the North Kennedy district of Queensland. *Austrobaileya* 8: 601–607. DOI

Jobson RW, Albert VA (2002) Molecular rates parallel diversification contrasts in carnivorous plant sister lineages. *Cladistics* 18: 127–136. DOI

Jobson RW, Baleeiro PC (2020) Radiations of fairy-aprons (*Utricularia dichotoma*, Lentibulariacceae) across eastern Australia: molecular evidence for new species and proposal for new subspecies. *Australian Systematic Botany* 33: 278–310. DOI

Jobson RW, Baleeiro PC (2022) Rescircumscription of *Utricularia leptorhyncha* and *U. lasiocaulis* and three related new species for northern Australia. *Telopea* 25: 363–383. DOI

Jobson RW, Baleeiro PC (2023). Molecular phylogenetic study of *Utricularia* section *Oligocista* in Australia and a new Cape York endemic species. *Telopea* 26: 145–158 DOI

Jobson RW, Baleeiro PC, Guisande C (2018) Systematics and evolution of Lentibulariaceae: III. *Utricularia*, Pg. 89–104, In Ellison A, Adamec L (Eds) *Carnivorous plants: physiology, ecology, and evolution*. Oxford University Press: Oxford.

Jobson RW, Baleeiro P, Reut M. (2017) Molecular phylogeny of subgenus *Polypompholyx* (*Utricularia*; Lentibulariaceae) based on three plastid markers: diversification and proposal for a new section. *Australian Systematic Botany* 30: 259–278. DOI

Jobson RW, Davies-Colley T (2020) Redescription of the suspended aquatic *Utricularia aurea* Lour. (sect. *Utricularia*) and a new species *U. adamsii* for northern Australia. *Telopea* 23: 21–33. DOI

Jobson RW, Playford J, Cameron KM, Albert VA (2003) Molecular phylogenetics of Lentibulariaceae inferred from plastid *rps*16 intron and *trn*L–F DNA sequences: implications for character evolution and biogeography. *Systematic Botany* 28: 157–171. DOI

Moar NT, Mason R (1975) Discovery of *Utricularia protrusa* Hook.f. near Westport, South Island, New Zealand. *New Zealand Journal of Botany* 13: 803–805. DOI

Müller K, Borsch T (2005) Phylogenetics of *Utricularia* (Lentibulariaceae) and molecular evolution of the *trnK* intron in a lineage with high substitutional rates. *Plant Systematics and Evolution* 250: 39–67. DOI

Oxelman B, Lidén M, Berglund D (1997) Chloroplast *rps*16 intron phylogeny of the tribe Sileneae (Caryophyllaceae). *Plant Systematics and Evolution* 206: 393–410. DOI

Posada D (2008) jModelTest: phylogenetic model averaging. *Molecular Biology and Evolution* 25: 1253–1256. DOI

Robins RJ, Subramanyam K (1980) Scanning electron microscope study of the seed surface morphology of some *Utricularia* (Lentibulariaceae) species from India. *Proceedings of the Indian National Science Academy* 46B: 310–324.

Ronquist F, Teslenko M, van der Mark P, Ayres DL, Darling A, Höhna S, Larget B, Liu L, Suchard MA, and Huelsenbeck JP (2012) MRBAYES 3.2: Efficient Bayesian phylogenetic inference and model selection across a large model space. *Systematic Biology* 61: 539–542. DOI

Salmon B (2001) *Carnivorous plants of New Zealand*. Auckland, Ecosphere Publications.

Shaw J, Shafer HL, Leonard OR, Kovach MJ, Schorr M, Morris AB (2005) The tortoise and the hare II: relative utility of 21 noncoding chloroplast DNA sequences for phylogenetic analysis. *American Journal of Botany* 92: 142–166. DOI

Silva SR, Miranda VF, Michael TP, Płachno BJ, Matos RG, Adamec L, Pond SL, Lucaci AG, Pinheiro DG, Varani AM (2023) The phylogenomics and evolutionary dynamics of the organellar genomes in carnivorous *Utricularia* and *Genlisea* species (Lentibulariaceae). *Molecular Phylogenetics and Evolution* 181, 107711. DOI

Stanford AM, Harden R, Parks CR (2000) Phylogeny and biogeography of *Juglans* (Juglandaceae) based on matK and ITS sequence data. *American Journal of Botany* 87: 872–882. DOI

White TJ, Bruns T, Lee S, Taylor JW (1990) Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In *PCR protocols: A guide to methods and applications*. (Eds MA Innis, DH Gelfand, JJ Sninsky, TJ White) pp. 315–322. Academic Press, Inc.: New York, NY, USA.

Taylor P (1989) The genus *Utricularia*. *Kew Bulletin Additional Series* 14. Royal Botanic Gardens: Kew.

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A genetic investigation of relationships and species boundaries between *Eucalyptus dalrympleana* and allied taxa in New South Wales

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Abstract

A revision of the classification of taxa in the *Eucalyptus dalrympleana* complex within *E.* series *Viminales* from New South Wales using population level genetic data is presented here. It remains unclear if the complex is a natural grouping to the exclusion of other related species, and hybridisation between members of the complex and *E. mannifera*, *E. viminalis* and *E. elliptica* is recorded. In line with observations from field surveys, the two taxa from the North Tablelands region, *E. dalrympleana* subsp. *heptantha* and *E. rubida* subsp. *barbigerorum* formed a single genetic lineage and the latter is therefore considered a synonym of the former, given this lineage is most closely related to *E. dalrympleana* subsp. *dalrympleana*. The threatened narrow-range endemic taxon *E. canobolensis* is shown to be nested within the more widespread *E. rubida* subsp. *rubida*, and therefore the original circumscription of this taxon as *E. rubida* subsp. *canobolensis* is supported.

Introduction

Eucalyptus rubida H.Deane & Maiden, *Eucalyptus dalrympleana* Maiden and *Eucalyptus canobolensis* (L.A.S.Johnson & K.D.Hill) J.T.Hunter form a complex of morphologically similar taxa in which it has historically proven difficult to draw species boundaries (here termed the *E. dalrympleana* complex), although it is widely recognised the three species form a natural grouping (Brooker *et al.* 2015; Nicolle 2024). A previous phylogenetic study of *Eucalyptus* sect. *Maidenaria* and relatives, including multiple representatives of all three species in the complex, was unable to resolve species level relationships within series *Viminales* (Jones *et al.* 2016), but provided moderate support for the three taxa being each other's closest relatives. In that study a sample of *E. darympleana* from Tasmania showed affinities to *E. viminalis,* possibly due to hybridisation, and a sample of *E. rubida* from Tasmania and *E. dalrympleana* from South Australia formed part of a polytomy near the base of series *Viminales*. All remaining samples of the three species (n = 17) formed an unsupported grouping in the phylogeny. In their follow-up publication to Jones *et al.* (2016), Nicolle and Jones (2018) provided a revised classification of *E.* section *Maidenaria*, which recognises ~40 species as members of *E.* ser. *Viminales*, which in turn consists of two subseries, *E.* subser. *Circulares* and *E.* subser. *Lanceolatae*. The *E. dalrympleana* complex was placed in *E.* subser. *Circulares*, although the particular relationship of the complex to other members of this subseries remains unclear.

Eucalyptus rubida was the first taxon described in the complex by Deane and Maiden (1899), with *E. dalrympleana* following shortly after, being described by Maiden and Flockton (1922). This two taxa system lasted 42 years before a new subspecies was erected within *Eucalyptus dalrympleana, E. dalrympleana* subsp. *heptantha* L.A.S.Johnson, which separated the populations of the Northern Tablelands of New South Wales and southern Queensland that typically have seven flowers per umbel from the typical three-flowered form that occurs south of these regions. More recently Nicolle (2022) recognised two new subspecies within *E. dalrympleana*, *E. dalyrmpleana* subsp. *lutruwita* Nicolle, which is endemic to Tasmania and includes all the populations from the island state, and *E. dalrympleana* subsp. *poliophylla* Nicolle from the highest elevations (>1200 m) of the Victorian Alps. This leaves *E. dalrympleana* subsp. *dalrympleana* with a distribution stretching from the Central Tablelands of NSW south through north-eastern Victoria, as well as isolated populations in the southern Mount Lofty Ranges in South Australia.

In the case of *E. rubida*, Hill and Johnson (1991) recognised three new subspecies based upon morphological and geographic variation:

- *Eucalyptus rubida* subsp. *septemflora* K.D.Hill & L.A.S.Johnson from the Kiewa River valley of Victoria was segregated based upon its seven flowered inflorescences, differing from the three flowered inflorescences otherwise typical of the species. However, as the seven-flowered form occurs amongst three flowered populations, most authorities today consider this taxon to represent occasional hybrids or a rare morphological variant of the typical subspecies, and therefore do not consider it a valid taxon (Brooker *et al.* 2015; Council of Heads of Australasian Herbaria 2016; Nicolle 2022, 2024).
- *Eucalyptus rubida* subsp. *canobolensis* K.D.Hill & L.A.S.Johnson was erected to recognise a population of trees on the upper slopes of Mount Canobolas in the Central Tablelands of NSW that exhibit a stunted growth form, larger leaves, and larger buds and fruit than the typical form of the species, as well as square stems on the seedlings and juvenile growth. Based upon comments by Maiden (1917) on the resemblance of *E. gunnii* Hook.f. from Tasmania and the Mt Canobolas population, and a morphological phylogenetic study by Chappill and Ladiges (1996) that suggested a closer relationship between these two taxa than between either and *Eucalyptus rubida* subsp. *rubida*, Hunter (1998) raised the population to the species level as *Eucalyptus canobolensis*. While this taxon is broadly accepted as a distinct species today, it is believed to be much more closely related to *Eucalyptus rubida* than to *Eucalyptus gunnii* (Brooker *et al.* 2015; Nicolle 2024).
- *Eucalyptus rubida* subsp. *barbigerorum* K.D.Hill & L.A.S.Johnson was erected to include scattered populations in the Northern Tablelands of NSW that exhibit elliptical juvenile leaves and a basal stocking of rough bark. It was noted in the description of this taxon that extensive intergradation occurred with *Eucalyptus dalrympleana* subsp. *heptantha*, and recent authors have suggested this could reflect the true affinity of the taxon (Hunter 2017).

In this study we use population-level sampling and reduced representation genetic data to investigate the relationships between *E. dalrympleana*, *E. rubida* and *E. canobolensis,* and subspecies thereof within NSW. To allow for a full understanding of the complex's relationship to other members of *E.* series *Viminales*, sampling of other taxa native to NSW within the group is also undertaken, which leads to some wider insights into the series' evolutionary history. This represents the first use of population-level genetic data in the *E. dalrympleana* complex and highlights the power of population genetics approaches in resolving shallow evolutionary relationships.

Methods

Sampling

Sampling for this study was limited to New South Wales and so affinities of populations outside the state cannot be commented on. *Eucalyptus rubida* was collected from 25 sites across NSW, including eight populations of *E. rubida* subspecies *barbigoreum* (Table 1 and Fig. 1a) while samples of *E. canobolensis* were collected from the only known population of the species. *Eucalyptus dalrympleana* was collected from 19 sites, split between 5 *E. dalrympleana* subsp. *dalrympleana* and 14 *E. dalrympleana* subsp. *heptantha* sites (Table 1 and Fig. 1b). The type populations of *E. dalrympleana* subsp. *heptantha*, *E. rubida* subsp. *barbigerorum* and *E. canobolensis* were all sampled to allow for the unambiguous taxonomic conclusions to be drawn.

Samples of several other members of *E.* series *Viminales* as defined by Nicolle and Jones (2018) were sampled as outgroups for the entire *E. dalrympleana* complex, focussing on species native to the Northern Tablelands of NSW (Table 1). Figure 2 shows the spatial spread of outgroup sampling. In all cases leaf samples were collected and placed into envelopes before drying either in silica gel or by freeze-drying. Voucher specimens were collected from a single sampled individual at most sites to confirm field identifications.

Where samples collected at a site did not show expected relationships, voucher identifications were reassessed and if a misidentification could be confirmed the new identification was employed. The two instances where this occurred are highlighted in Table 1, including a site where all samples were identified as *E. rubida* subsp. *rubida* in the field but that was subsequently determined to be *E. dalrympleana* subsp. *dalrympleana*, and a site where all samples were identified as *E. rubida* subsp. *rubida* in the field, but that genetic data showed that one sample, which happened to be the vouchered sample, was actually a misidentified *E. viminalis* individual, with the remaining samples all within the *E. rubida* subsp. *rubida* clusters in genetic analyses suggesting that field identifications were correct.

Table 1. Sample and collection location information for *Eucalyptus* series *Viminales* taxa genotyped in this study. All samples of a species collected within 5 km of one another are grouped into a site, with the number of samples which met data quality thresholds for each site shown.

Taxon and classification per Nicolle (2024)	Site	Samples in final dataset	GPS locations	Representative herbarium voucher collected from site
E. rubida subsp. *rubida* (series *Viminales* subseries *Circulares*)	Bucky Springs Rd - ~2.8 km SE of Bombala, NSW	NSW1197181	-36.92281, 149.26110	
		NSW1197186	-36.92277, 149.26113	
		NSW1197137	-36.92277, 149.26109	
		NSW1197112	-36.92275, 149.26113	
		NSW1197107	-36.92265, 149.26103	
E. rubida subsp. *rubida*	Barry Way - ~5.5 km S of Grosses Plain, NSW	NSW1197251	-36.61317, 148.49158	NSW1197135
		NSW1197226	-36.61405, 148.49197	
		NSW1197231	-36.61375, 148.49177	
		NSW1197236	-36.61354, 148.49187	
		NSW1197241	-36.61344, 148.49175	
		NSW1197246	-36.61327, 148.49156	
E. rubida subsp. *rubida*	Snowy Mountains Hwy - ~5.7 km WNW of Adaminaby, NSW	NSW1197200	-35.98312, 148.72607	NSW1197151
		NSW1197195	-35.98346, 148.72636	
		NSW1197270	-35.98335, 148.72618	
		NSW1197235	-35.98332, 148.72614	
		NSW1197265	-35.98312, 148.72589	
		NSW1197117	-35.98284, 148.72577	
E. rubida subsp. *rubida*	Namadgi National Park, ~5.7 km from Boboyan Rd along Nass Valley Firetrail, ACT	JJB3613	-35.85031, 149.04436	NE 110462
E. rubida subsp. *rubida*	Coppabella Rd, Opposite Rosewood Cemetery, Rosewood, NSW	NSW1197095	-35.69046, 147.86218	NSW1197357
		NSW1197274	-35.69256, 147.86168	
		NSW1197080	-35.69252, 147.86161	
		NSW1197085	-35.69135, 147.86129	
		NSW1197090	-35.69079, 147.86153	
		NSW1197275	-35.69064, 147.86171	
E. rubida subsp. *rubida*	Burra Rd, Tinderry Nature Reserve, NSW	NSW1197188	-35.62512, 149.21671	NSW1197130
		NSW1197190	-35.62540, 149.21670	
		NSW1197189	-35.62532, 149.21661	
		NSW1197182	-35.62524, 149.21674	
		NSW1197187	-35.62523, 149.21693	
		NSW1197177	-35.62518, 149.21662	
E. rubida subsp. *rubida*	Tidbinbilla Rd, Greenway, ACT	JJB3612	-35.45678, 149.01114	NE 108977
E. rubida subsp. *rubida*	Doctors Flat Rd, ~1 km SE of Waddys Plain, NSW			NSW1176522 [sequence failed]
		NSW1176526	-35.10250, 148.75647	
		NSW1144548	-35.10248, 148.75647	
		NSW1176531	-35.10241, 148.75631	
		NSW1144358	-35.10237, 148.75633	
		NSW1144359	-35.10234, 148.75634	
E. rubida subsp. *rubida*	Marked Tree Rd, Mcleods Creek Nature Reserve, NSW	NSW1147789	-35.01687, 149.28573	NSW1144397
		NSW1147794	-35.01735, 149.28542	
		NSW1147793	-35.01733, 149.28531	
		NSW1147788	-35.01718, 149.28553	
		NSW1147799	-35.01713, 149.28545	
		NSW1147798	-35.01712, 149.28544	

Taxon and classification per Nicolle (2024)	Site	Samples in final dataset	GPS locations	Representative herbarium voucher collected from site
				NSW1144540 - [sequence failed]
E. rubida subsp. *rubida*	Targo TSR, ~10 km NE of Kenmore, NSW	NSW1144542	-34.61778, 149.79907	
		NSW1144557	-34.61776, 149.79894	
		NSW1144552	-34.61772, 149.79854	
		NSW1144620	-34.61772, 149.79892	
		NSW1144567	-34.61763, 149.79905	
E. rubida subsp. *rubida*	Lachlan Valley Way, ~7.4 km NW of Kangiara, NSW	NSW1176466	-34.58313, 148.73704	NSW1176453
		NSW1176460	-34.58339, 148.73723	
		NSW1176465	-34.58296, 148.73706	
		NSW1176476	-34.58296, 148.73693	
		NSW1176471	-34.58294, 148.73687	
		NSW1176470	-34.58290, 148.73690	
E. rubida subsp. *rubida*	Berrima Reserve Campground	NSW1144483	-34.48497, 150.33227	NSW1144498
		NSW1144489	-34.48503, 150.33223	
		NSW1144484	-34.48498, 150.33216	
		NSW1144499	-34.48483, 150.33262	
		NSW1144494	-34.48482, 150.33264	
		NSW1144495	-34.48473, 150.33258	
E. rubida subsp. *rubida*	Funny Hill TSR, ~4.4 km NNW of Binda, NSW	NSW1175697	-34.28660, 149.34723	NSW1175692
		NSW1175702	-34.28662, 149.34720	
		NSW1175707	-34.28672, 149.34731	
		NSW1175712	-34.28687, 149.34722	
		NSW1175717	-34.28718, 149.34710	
		NSW1175722	-34.28725, 149.34736	
E. rubida subsp. *rubida*	Hyde Park Bushland Reserve, Hartley, NSW	NSW1197333	-33.53312, 150.18869	NSW1197284
		NSW1197279	-33.53290, 150.18872	
		NSW1197289	-33.53304, 150.18857	
		NSW1197290	-33.53287, 150.18838	
		NSW1197294	-33.53308, 150.18865	
		NSW1197299	-33.53293, 150.18869	
E. rubida subsp. *rubida*	Carcoar Rd, ~2.5 km NNW Browns Creek, NSW	DDA143	-33.50472, 149.13228	NE 109691
		DDA143a	-33.50497, 149.13236	
		DDA143b	-33.50489, 149.1321	
		DDA143c	-33.50408, 149.13178	
		DDA143d	-33.50300, 149.13192	
E. rubida subsp. *rubida*	Ophir Rd, ~7.5 km N of Orange, NSW	DDA139	Site GPS: -33.23475, 149.13244	NE 109687
		DDA139a		
		DDA141a	-33.21317, 149.13669	NE 109689
		DDA141b	-33.21239, 149.13711	
E. rubida subsp. *rubida*	Long Point Rd, ~5 km NE of Mullions Creek, NSW	NSW1175640	-33.11138, 149.14818	NSW1175641
		NSW1175634	-33.11179, 149.14801	
		NSW1175638	-33.11178, 149.14802	
		NSW1175639	-33.11137, 149.14820	
		NSW1175703	-33.11178, 149.14802	

Taxon and classification per Nicolle (2024)	Site	Samples in final dataset	GPS locations	Representative herbarium voucher collected from site
E. rubida subsp. *barbigerorum* (series *Viminales* subseries *Circulares*)	Forest Way, Nundle State Forest, NSW	DDA255	-31.43883, 151.40906	NE 111727
		DDA255a	-31.43817, 151.40958	
		DDA255c	-31.43853, 151.40964	
		DDA255d	-31.43903, 151.40903	
E. rubida subsp. *barbigerorum*	Thungatti Campground, New England National Park, NSW	DDA259	-30.50197, 152.38767	NE 111731
		DDA259a	-30.50167, 152.38833	
		DDA259b	-30.50192, 152.38817	
		DDA259c	-30.50214, 152.38722	
		DDA259d	-30.50194, 152.38822	
E. rubida subsp. *barbigerorum*	Moredun TSR, Wandsworth, NSW			NSW1187967 [sequence failed]
		NSW1188090	-30.00180, 151.47598	
		NSW1192862	-30.00002, 151.47556	
		NSW1192863	-30.00002, 151.47556	
		NSW1192864	-30.00025, 151.47542	
		NSW1192865	-30.00054, 151.47559	
E. rubida subsp. *barbigerorum*	**Type population:** Wandsworth TSR, Wandsworth, NSW	DDA204	-29.96872, 151.43569	NE 110896
		DDA204a	-29.96897, 151.46861	
		DDA204c	- 29.96894, 151.46950	
E. rubida subsp. *barbigerorum*	Flaggy Creek, Pinkett, NSW		-29.91025, 151.96967	NE 110977
		DDA221a	-29.91000, 151.96986	
		DDA221b	-29.91017, 151.97003	
		DDA221c	-29.91033, 151.97000	
		DDA221d	-29.91042, 151.96969	
E. rubida subsp. *barbigerorum*	Strathbogie road, ~11.7km NW of Glen Innes, NSW	DDA49	-29.66793, 151.64515	NE 108224
		DDA50	-29.66825, 151.64562	NE 108227
		DDA51	-29.66665, 151.64545	NE 108230
		DDA54	-29.66723, 151.64445	NE 108326
E. rubida subsp. *barbigerorum*	Near eastern entrance road to Gibraltar House, Gibraltar Range National Park, NSW		-29.51367, 152.31311	NE 111246
		DDA227a	-29.51175, 152.31342	
		DDA227b	-29.51300, 152.31222	
		DDA227c	-29.51261, 152.31300	
		DDA227d	-29.51444, 152.31300	
		DDA227e	-29.51469, 152.31211	
E. rubida subsp. *barbigerorum*	Chaelundi Campground, Chaelundi National Park, NSW		Site GPS: -30.06830, 152.33300	NE 114906
		DDA313a		
		DDA313b		
		DDA313c		
		DDA313d		
		DDA313e		
E. canobolensis (series *Viminales* subseries *Circulares*)	**Type population:** Junction of Old Canobolas Rd and Towac Way, Mount Canobolas, NSW			NSW1196982 - [sequence failed]
		NSW1196988	-33.34232, 148.97787	
		NSW1196993	-33.34230, 148.97772	
		NSW1196998	-33.34226, 148.97767	
		NSW1197003	-33.34226, 148.97767	

Taxon and classification per Nicolle (2024)	Site	Samples in final dataset	GPS locations	Representative herbarium voucher collected from site
E. dalrympleana subsp. *dalrympleana*	Boboyan Rd, Namadgi National Park, ACT	JJB3614	Site GPS: -35.83525, 149.00969	NE 110463
		JJB3614a		
		JJB3614b		
		JJB3614c		
		JJB3614d		
E. dalrympleana subsp. *dalrympleana* [collected as *E. rubida* subsp. *rubida*]	Bushland next to Hobbys Yards Tip, ~3 km S from Hobby Yards, NSW	NSW1175762	-33.73216, 149.33515	NSW1175751
		NSW1175745	-33.73223, 149.33578	
		NSW1175750	-33.73224, 149.33579	
		NSW1175755	-33.73222, 149.33589	
		NSW1175756	-33.73222, 149.33595	
		NSW1175761	-33.73228, 149.33600	
E. dalrympleana subsp. *dalrympleana*	Kerl Rd, ~12 km S of Orange, NSW	DDA146	-33.38272, 149.04375	NE 109694
		DDA146a	-33.38275, 149.04358	
		DDA146b	-33.38272, 149.04339	
		DDA146c	-33.38267, 149.04333	
		DDA146d	-33.38264, 149.04311	
E. dalrympleana subsp. *dalrympleana*	Gum Ridge Trail, Mt Canobolas, NSW	DDA117	-33.35625, 148.95997	NE 109667
		DDA117a	-33.35581, 148.96031	
		DDA117b	-33.35564, 148.96039	
		DDA117c	-33.35531, 148.96044	
		DDA117d		
E. dalrympleana subsp. *heptantha* (series *Viminales* subseries *Circulares*)	Forest Rd, Coolah Tops National Park, NSW	DDA247	-31.73356, 150.02917	NE 111507
		DDA247a	-31.73353, 150.02922	
		DDA247b	-31.73344, 150.02897	
		DDA247c	-31.73361, 150.02869	
		DDA247d	-31.73353, 150.02803	
E. dalrympleana subsp. *heptantha*	Blue Mountain Rd, ~15 km NE of Walcha, NSW	DDA216	-30.88217, 151.68350	NE 110972
		DDA216a	-30.88278, 151.68333	
		DDA216b	-30.88233, 151.68325	
		DDA216c	-30.88169, 151.68319	
		DDA216d	-30.88122, 151.68314	
E. dalrympleana subsp. *heptantha*	Gostwyck Rd, ~2.5 km W of Mihi, NSW	MWH36	-30.71065, 151.64570	NE 113376
E. dalrympleana subsp. *heptantha*	Woodridge Fossicking and Recreation Area, ~3 km WNW of Uralla, NSW	JWC20	-30.62833, 151.47194	NE 109727
		JWC20ai	Cultivated from JWC20a	
		JWC20aiii	Cultivated from JWC20a	
		JWC20b		
		JWC20ii	Cultivated from JWC20	
E. dalrympleana subsp. *heptantha*	Point Lookout Rd, ~6 km E of intersection with Waterfall Way, NSW	DDA260	-30.49161, 152.34892	NE 111732
		DDA260a	-30.49167, 152.34826	
		DDA260b	-30.49176, 152.34852	
		DDA260c	-30.49190, 152.34905	

Taxon and classification per Nicolle (2024)	Site	Samples in final dataset	GPS locations	Representative herbarium voucher collected from site
E. dalrympleana subsp. *heptantha*	Kanoona road, Armidale, NSW	DDA100	-30.48669, 151.75902	NE 109152
		DDA100a	-30.48672, 151.75875	
		DDA100b	-30.48654, 151.75900	
		DDA101	-30.48683, 151.75889	
		DDA101a	-30.48688, 151.75897	
		DDA101b	-30.48696, 151.75892	
E. dalrympleana subsp. *heptantha*	Boorolong Rd, ~10 km NW of Armidale, NSW	MWH25	-30.45265, 151.56907	NE 112964
E. dalrympleana subsp. *heptantha*	Newholme, ~1.4 kms East of Dumaresq Dam, Armidale, NSW	DDA29	-30.42617, 151.61425	NE 107949
		DDA30	-30.42714, 151.61528	NE 107950
		DDA31	-30.42753, 151.61558	NE 107951
E. dalrympleana subsp. *heptantha*	Newholme Rd, ~3.5 km W of intersection with New England Highway, NSW	GC28	-30.42292, 151.64719	NE 108301
		GC28b	-30.42286, 151.64714	
		GC28c	-30.42294, 151.64714	
E. dalrympleana subsp. *heptantha*	~12.5 km NW of Armidale, NSW	NSW1043530	Site GPS: -30.40175, 151.62558	
		NSW1043567		
		NSW1043587		
		NSW1043588		
		NSW1043622		
		NSW1043628		
E. dalrympleana subsp. *heptantha*	Avondale State Conservation Area, NSW	DDA88	-30.35419, 152.00319	NE 109129
		DDA88a	-30.35411, 152.00311	
		DDA88b	-30.35425, 152.00303	
		DDA88c	-30.35428, 152.00300	
		DDA88d	-30.35419, 152.00289	
		DDA88e	-30.35408, 152.00289	
E. dalrympleana subsp. *heptantha*	Wards Mistake Rd TSR, Bald Blair, NSW	DDA219	-30.14789, 151.81983	NE 110976
		DDA219a	-30.14772, 151.82056	
		DDA219b	-30.14800, 151.82039	
		DDA219c	-30.14817, 151.82003	
		DDA219d	-30.14847, 151.82000	
E. dalrympleana subsp. *heptantha*	Guyra Rd, ~13 km NW of Guyra, NSW	MWH28	-30.14183, 151.58034	NE 112967
E. dalrympleana subsp. *heptantha*	Guyra Rd, ~15km NW of Guyra, NSW	NSW1043606	Site GPS: -30.13578, 151.55108	NSW1043606
		NSW1043547		
		NSW1044799		
		NSW1044805		
E. dalrympleana subsp. *heptantha*	**Type population:** Wandsworth TSR, ~26 km NW of Guyra, NSW	MWH40a	-30.03396, 151.50117	NE 113379
		DDA203	-30.03217, 151.50114	NE 110895
		DDA203a	30.03233, 151.50117	
		DDA203b	-30.03233, 151.50147	
		DDA203c	-30.03256, 151.50167	
		DDA203d	-30.03281, 151.50197	
		DDA203e	-30.03325, 151.50200	
E. cinerea subsp. *cinerea* (series *Viminales* subseries *Circulares*)	Cultivated at Australian Botanic Gardens Mount Annan, NSW	NSW1175008		ABG living collection: A2001-0815/5A
		NSW1175009		ABG living collection: 2004-0413/5

Taxon and classification per Nicolle (2024)	Site	Samples in final dataset	GPS locations	Representative herbarium voucher collected from site
E. lactea (series *Viminales* subseries *Circulares*)	Hidden Trail, Gardens of Stone National Park	NSW1047486	-33.22054, 150.02715	NSW1048580
		NSW1047485	-33.22072, 150.02746	NSW1048582
		NSW1047492	-33.21969, 150.02488	NSW1048588
		NSW1045236	-33.22035, 150.02592	
		NSW1045237	-33.22035, 150.02592	
		NSW1045238	-33.21950, 150.02497	
		NSW1045373	-33.22035, 150.02672	
E. lactea	Coricudgy Rd, Wollemi National Park, NSW	NSW1045227	Site GPS: -32.85563, 150.22936	
		NSW1045228		
		NSW1045229		
E. elliptica (series *Viminales* subseries *Circulares*)	New England Highway TSR, ~15 km NE of Bendemeer, NSW	DDA239	-30.78764, 151.27736	NE 111498
		DDA239b	-30.78782, 151.27729	
		DDA239c	-30.78740, 151.27800	
		DDA239d	-30.787440, 151.27809	
E. elliptica	Dawson's Springs Nature Trail, Mt Kaputar National Park, NSW	DDA238	Site GPS: -30.27933, 150.16489	NE 111497
		DDA238a		
		DDA238b		
		DDA238c	-30.28133, 150.16372	
		DDA238d	-30.28164, 150.16350	
		DDA238e	-30.28164, 150.16372	
E. acaciiformis (series *Viminales* subseries *Lanceolatae*)	Rockvale road, c.1 km SE of Boundary Creek NSW	DDA306	Site GPS: -30.31200, 151.96500	NE 113625
		DDA306a		
		DDA306b		
		DDA306c		
		DDA306d		
E. dorrigoensis (series *Viminales* subseries *Lanceolatae*)	**Type population:** Coramba road, Megan, NSW	DDA228	-30.28278, 152.77603	NE 111247
		DDA228a	-30.28272, 152.77608	
		DDA228b	-30.28281, 152.77622	
		DDA228c	-30.28275, 152.77700	
		DDA228d	-30.28261, 152.77750	
E. dorrigoensis	London Bridge Trail, Oakwood Flora Reserve, NSW	NSW1018019	-29.92043, 152.09882	NSW1022169
		NSW1018079	-29.91693, 152.09788	
E. mannifera subsp. *mannifera* (series *Viminales* subseries *Lanceolatae*)	Burra Rd, ~3 km S of Burra, NSW	NSW1030053	-35.58522, 149.22930	NSW1029689
		NSW1030049	-35.58500, 149.22931	
		NSW1030050	-35.58509, 149.22925	
		NSW1030051	-35.58543, 149.22931	
		NSW1030052	-35.58537, 149.22934	
		NSW1030054	-35.58500, 149.22919	
E. nicholii (series *Viminales* subseries *Lanceolatae*)	New Valley Fire Trail, Single National Park, NSW	DDA242	-30.01800, 151.38844	NE 111503
		DDA242a	-30.01775, 151.38836	
		DDA242b	-30.01797, 151.38825	
		DDA242c	-30.01839, 151.38825	
		DDA242d	-30.01794, 151.38847	

Taxon and classification per Nicolle (2024)	Site	Samples in final dataset	GPS locations	Representative herbarium voucher collected from site
E. nobilis (series *Viminales* subseries *Lanceolatae*)	Wild Cattle Creek Rd, Nowendoc State Forest, NSW	DDA208	-31.41000, 151.57936	NE 110921
		DDA208a	-31.41000, 151.57936	
		DDA208b	-31.41008, 151.57947	
		DDA208c	-31.41008, 151.57928	
		DDA208d	-31.41022, 151.58006	
		DDA208e	-31.41050, 151.58069	
E. nobilis	Point Lookout Rd TSR, Ebor, NSW		-30.48653, 152.32831	NE 109130
		DDA89a	-30.48650, 152.32825	
		DDA89b	-30.48678, 152.32853	
		DDA89c	-30.48689, 152.32833	
		DDA89d	-30.48717, 152.32914	
		DDA89e	-30.48722, 152.32953	
		DDA89f	-30.48697, 152.32983	
E. nobilis	Summit Trail, Duval Nature Reserve, NSW	DDA20	-30.40481, 151.63142	NE 107558
		DDA21	-30.40472, 151.63147	NE 107559
		DDA22	Site GPS: -30.40839, 151.64206	NE 107942
		DDA22a		
		DDA22c		
		DDA22d		
		DDA22e		
E. nobilis	Wards Mistake Rd TSR, Bald Blair, NSW	DDA220	-30.14294, 151.82450	NE 110975
		DDA220a	-30.14264, 151.82464	
		DDA220b	-30.14244, 151.82478	
		DDA220c	-30.14336, 151.82450	
E. nova-anglica (series *Viminales* subseries *Lanceolatae*)	Guyra Rd, ~6.5 km W of Wongwibinda, NSW	NSW1193132	-30.28201, 152.12193	NSW1187924
		NSW1193150	-30.28188, 152.12262	
		NSW1193151	-30.28193, 152.12230	
		NSW1193152	-30.28210, 152.12177	
		NSW1193153	-30.28173, 152.12222	
		NSW1193154	-30.28161, 152.12263	
E. nova-anglica	Oakey Creek Pullover, Waterfall Way, NSW	NSW1193200	-30.49984, 152.25358	NSW1089654
		NSW1188049	-30.50034, 152.25347	
		NSW1188051	-30.50086, 152.25346	
		NSW1193134	-30.50019, 152.25321	
		NSW1193201	-30.50044, 152.25331	
		NSW1193202	-30.50037, 152.25294	
E. nova-anglica	Guyra Ebor road T.S.R, ~10 km E of Guyra, NSW	DDA201	-30.22610, 151.77720	NE 110901
		DDA201a	-30.22613, 151.77727	
		DDA201b	-30.22606, 151.77713	
E. nova-anglica	**Type population:** Bukeiro road, Moona Plains, NSW	DDA309	Site GPS: -30.99630, 151.89360	NE 113768
		DDA309a		
		DDA309b		
		DDA309c		
		DDA309d		

Taxon and classification per Nicolle (2024)	Site	Samples in final dataset	GPS locations	Representative herbarium voucher collected from site
E. viminalis subsp. *viminalis* (series *Viminales* subseries *Lanceolatae*	Mountain Creek Rd, Tidbinbilla Nature Reserve, ACT	JJB3608	-35.45881, 148.89617	NE 108971
		JJB3609	-35.45906, 148.89406	NE 108972
		JJB3610	-35.45839, 148.89181	NE 108973
		JJB3607	-35.45931, 148.89775	NE 108970
		JJB3611	-35.45678, 148.88953	NE 108976
E. viminalis subsp. *viminalis* [collected as *E. rubida* subsp. *rubida*]	Bucky Springs Rd, ~2.8 km SE of Bombala, NSW	NSW1197127	-36.92263, 149.26104	NSW1197125
E. viminalis subsp. *viminalis*	Kowmung River Trail at Kowmung River crossing, NSW	NSW1032935	-33.95630, 149.97893	NSW1029295
		NSW1032926	-33.95617, 149.97868	
		NSW1032927	-33.95597, 149.97756	
		NSW1032928	-33.95568, 149.97687	
		NSW1032930	-33.95602, 149.97825	
E. viminalis subsp. *viminalis*	Jenolan, NSW	NSW1027202	-33.81580, 150.02214	NSW1028616
		NSW1027199	-33.81544, 150.02127	
		NSW1027200	-33.81436, 150.02086	
		NSW1027201	-33.81584, 150.02260	
		NSW1027203	-33.81605, 150.02248	
		NSW1027204	-33.81557, 150.02162	
E. viminalis subsp. *viminalis*	Katoomba View Lookout, Jenolan, NSW	NSW1033192	-33.79050, 150.03232	
		NSW1033193	-33.79060, 150.03232	
		NSW1033194	-33.79058, 150.03202	
		NSW1033195	-33.79057, 150.03153	
E. viminalis subsp. *viminalis*	Gosling Creek Reserve, Orange, NSW	DDA149	Site GPS: -33.32975, 149.08297	NE 109698
		DDA149a		
		DDA149b		
		DDA149c		
		DDA149e		
E. viminalis subsp. *viminalis*	Cox's Creek Rd, Rylston, NSW	DDA114	-32.75272, 150.07375	NE 109664
		DDA114a	-32.75258, 150.07422	
		DDA114b	-32.75257, 150.07399	
		DDA114c	-32.75252, 150.07393	
		DDA114d	-32.75263, 150.07375	
		DDA114e	-32.75314, 150.07361	
E. viminalis subsp. *viminalis*	Brackendale road, ~30.0km SSE of Walcha, NSW	DDA222	-31.24158, 151.71003	NE 110978
		DDA222a	-31.24172, 151.70983	
		DDA222b	-31.24117, 151.70986	
		DDA222c	-31.24094, 151.70944	
		DDA222d	-31.24142, 151.70947	
E. viminalis subsp. *viminalis*	Jalna Rd TSR, ~3 km SW of Bendemeer, NSW	DDA213	-30.90614, 151.13039	NE 110969
		DDA213a	-30.90561, 151.12967	
		DDA213b	-30.90597, 151.13050	
		DDA213c	-30.90633, 151.13164	
		DDA213d	-30.90644, 151.13242	
		DDA213e	-30.90686, 151.13550	

Taxon and classification per Nicolle (2024)	Site	Samples in final dataset	GPS locations	Representative herbarium voucher collected from site
E. viminalis subsp. *viminalis*	Hill View Rd, ~3.5km W of intersection with Thunderbolts Way, NSW	DDA217	-30.80314, 151.57814	NE 110973
		DDA217a	-30.80331, 151.57842	
		DDA217b	-30.80342, 151.57853	
		DDA217c	-30.80342, 151.57872	
		DDA217d	-30.80325, 151.57822	
E. viminalis subsp. *viminalis*	Gostwyck Rd, ~2.5 km W of Mihi, NSW	MWH35	-30.71138, 151.64625	NE 113375
		MWH37	-30.70890, 151.64819	NE 11337
E. viminalis subsp. *viminalis*	Waterfall Way, ~5 km E of Armidale, NSW	MWH43a	-30.52706, 151.70217	NE 113383
E. viminalis subsp. *viminalis*	University of New England, Armidale, NSW	MWH22b	-30.48536, 151.63775	NE 112521
		DDA102	-30.48206, 151.63975	NE 109158
		DDA102a	-30.48186, 151.63978	
		DDA102b	-30.48159, 151.64021	
		DDA102c	-30.48164, 151.64050	
		DDA102d	-30.48172, 151.64011	
		DDA102e	-30.48212, 151.63990	
E. viminalis subsp. *viminalis*	Cachs Creek TSR, ~34 km WNW of Armidale, NSW	DDA207	-30.40331, 151.31903	NE 110899
		DDA207a	-30.40339, 151.31908	
		DDA207b	-30.40317, 151.31964	
		DDA207c	-30.40342, 151.31919	
		DDA207d	-30.40328, 151.31789	
		DDA207e	-30.40367, 151.31681	
E. viminalis subsp. *viminalis*	3003 Rockvale Rd, Thalgarrah, NSW	DDA263	-30.39597, 151.92928	NE 112253
		DDA263a	-30.39556, 151.92894	
		DDA263b	-30.39575, 151.92872	
		DDA263c	-30.39669, 151.92853	
		DDA263d	-30.39722, 151.92883	
E. viminalis subsp. *viminalis*	Guyra-Ebor Rd TSR, Green Hills, NSW	DDA200a	Site GPS: -30.22609, 151.77685	NE 110900
		DDA200b		
		DDA200c		
		DDA200d		
		DDA200e		
		DDA200f		
E. viminalis subsp. *viminalis*	Frazer's Creek TSR, Nullamanna, NSW	DDA223	-29.64586, 151.23325	NE 111239
		DDA223a	-29.64581, 151.23300	
		DDA223b	-29.64586, 151.23292	
		DDA223c	-29.64628, 151.23311	
		DDA223d	-29.64722, 151.23336	
		DDA223e	-29.64658, 151.23300	
E. viminalis subsp. *viminalis*	Nullamanna Rd TSR, Wellingrove, NSW	DDA224	-29.51875, 151.39828	NE 111240
		DDA224a	-29.51875, 151.39725	
		DDA224b	-29.51889, 151.39689	
		DDA224c	-29.51847, 151.39808	
		DDA224d	-29.51808, 151.39881	

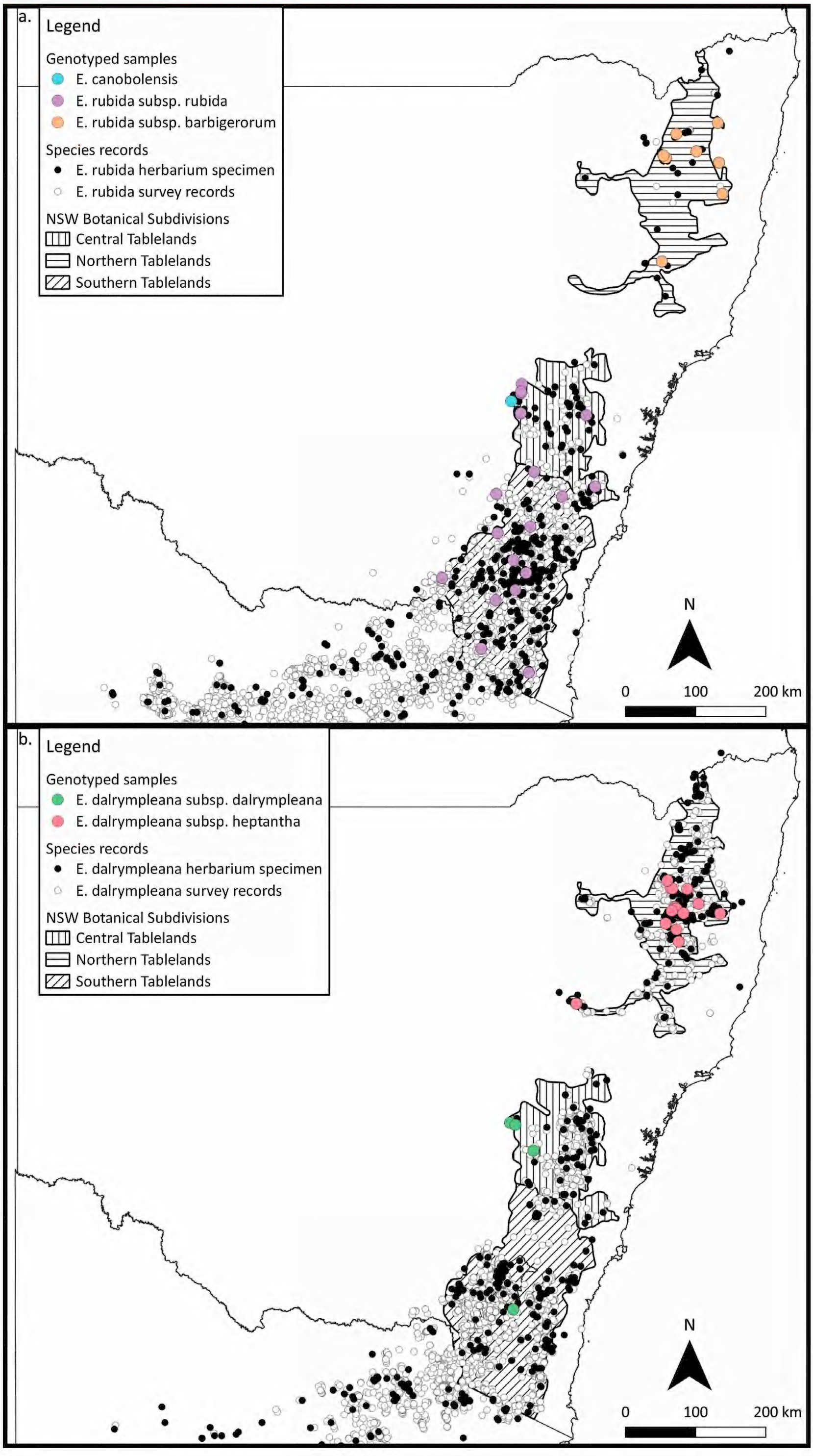

Figure 1. Maps showing geographic locations of collections of (a) *E. rubida* and *E. canobolensis;* and (b) *E. dalrympleana* overlaid upon herbarium specimen collection localities and survey records downloaded from the Atlas of Living Australia (Atlas of Living Australia 2024). Also shown are the three botanical subdivision of NSW they occur in, the Northern Tablelands (horizontal hashing), Central Tablelands (vertical hashing), and Southern Tablelands (diagonal hashing).

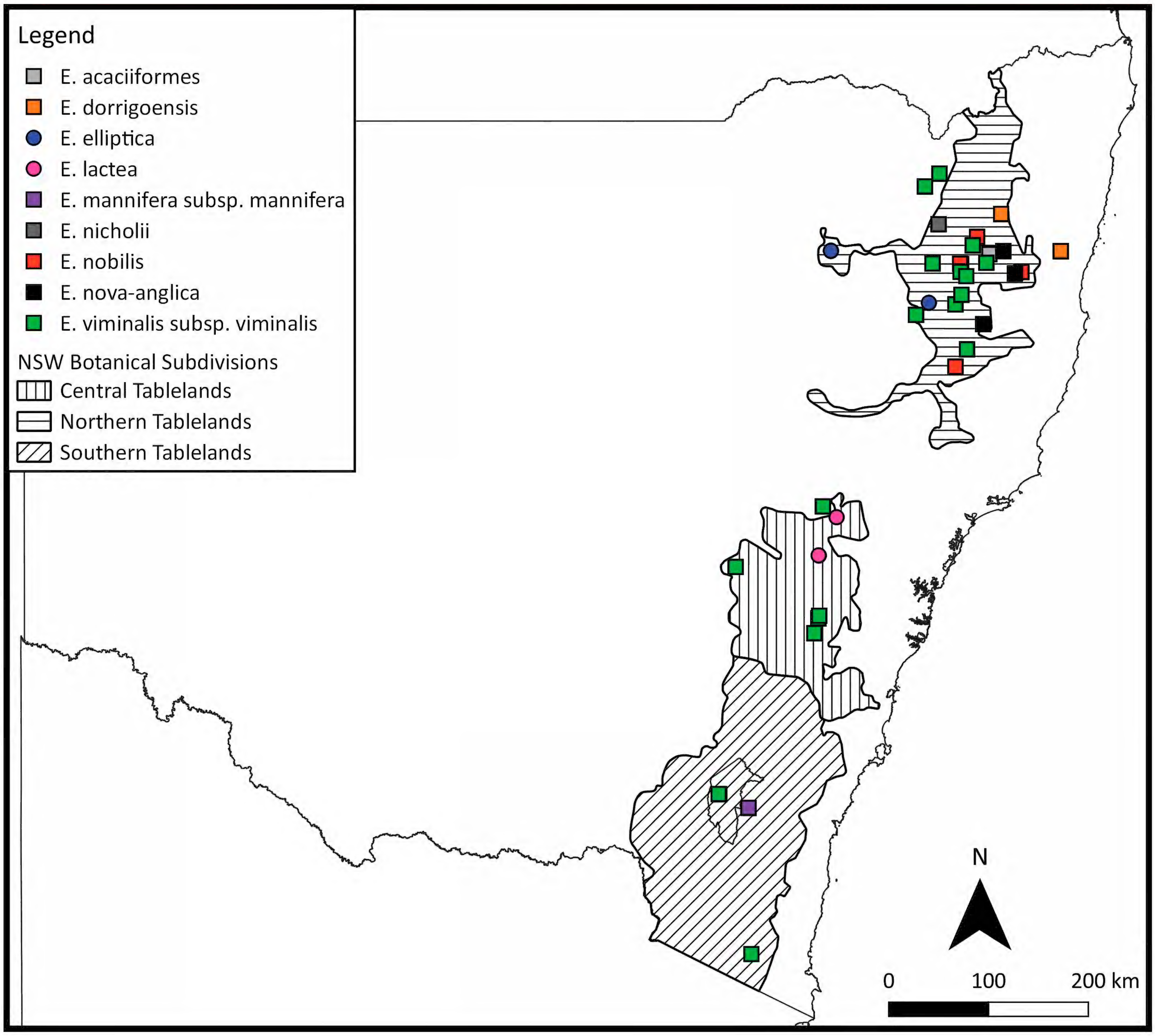

Figure 2. Map showing the collecting localities of outgroup samples included in this study. Points are coloured by taxon and shapes indicated subseries assignment in Nicolle and Jones' (2018) classification: circles indicate members of *E.* subser. *Circulares* and squares indicate members of *E.* subser. *Lanceolatae*. Also shown are the three botanical subdivision of NSW they occur in, the Northern Tablelands (horizontal hashing), Central Tablelands (vertical hashing), and Southern Tablelands (diagonal hashing).

DArTseq data generated and analysis.

Small amounts (~10 mg) of dried leaf tissue from each sample were sent to Diversity Array Technologies Pty Ltd (Canberra) for DNA extraction and sequencing using the DArTseq platform, generating tens of thousands of single nucleotide polymorphisms (SNPs) across the sampled individuals (Sansaloni *et al.* 2010; Sansaloni *et al.* 2011; Kilian *et al.* 2012). The returned *SNP_mapping* formatted SNP dataset was filtered using the *RRtools* package (Rossetto *et al.* 2019) in *R* (R Development Core Team 2016) to remove any individuals with > 50% missing data, along with SNPs with call rates < 80% and minor allele frequencies of < 0.05. SNPs were then subsampled to include only one SNP per sequenced locus meaning the final dataset contained only SNPs with high probability of being unlinked within the genome. A matrix of Euclidean genetic distances between all samples was then calculated using the *dist* function and exported to a nexus file. This file was used to visualise a phylogenetic network in the *splitstree 4* program (Huson and Bryant 2006) using default parameters, to test if the *E. dalrympleana* complex formed a single genetic cluster to the exclusion of all other sampled taxa and to identify any potentially hybrid samples for removal before further analyses.

A secondary dataset was also created by first removing all samples not belonging to the *E. dalrympleana* complex and then performing that same filtering steps as used for the complete dataset. A PCA was then performed on this SNP dataset using the *glPca* function from the *adegenet* package (Jombart 2008; Jombart and Ahmed 2011). In parallel to this, the *dartR* package (Gruber *et al.* 2018) was used to read the *SNP* formatted file provided by DArT, removing all samples with > 50% missing data, and non-*E. dalrympleana* complex samples. The same loci filtering parameters as used previously were also applied, namely a call rate threshold of 80%, reproducibility threshold

of 0.96, and subsampling to one SNP per sequenced locus. This dataset was then randomly subsampled to 5000 SNP to decrease computational requirements for downstream analysis and written to a *STRUCTURE* formatted file. Five replicate runs of *STRUCTURE* (Pritchard *et al.* 2000) were then performed on this dataset for values of K (cluster number) of one through six. All replicates were run for 50 000 burnin replications, and a further 100 000 MCMC replications, and MCMC chains were checked for parameter convergence, which was reached during the burnin in all cases. *StructureHarvester* (Earl and vonHoldt 2011) was then used to collate replicates and investigate the performance of different values of K by inspecting posterior probabilities and employing the *Evanno* method (Evanno *et al.* 2005).

Results

Data quality and filtering

From the raw dataset of 66 087 SNPs and 415 samples, a total of 17 165 SNPs passed quality filtering, with 384 samples included in the filtered series *Viminales* dataset, and 201 samples in the *E. dalrympleana* complex dataset. All datasets are available on request from the authors.

Broader phylogenetic network of series Viminales

Figure 3 shows the *splitstree* network including all samples of species in series *Viminales*. Broadly the clustering corresponds to the classification of Nicolle (2024), however *E. mannifera* subsp. *mannifera* appears to be a member of subseries C*irculares* most closely related to *E. cinerea* and *E. lactea*, the latter of which is considered *E. mannifera* subsp. *praecox* by the APC (Council of Heads of Australasian Herbaria 2016). Of the subseries *Lanceolatae* species, close relatives *E. nicholii* and *E. acaciiformis* formed a cluster with *E. nova-anglica*, and *E. viminalis* subsp. *viminalis*, *E. nobilis* and *E. dorrigoensis* each formed discreet clusters. It was not clear that the *E. dalrympleana* complex formed a natural grouping in our genetic data, as *E. elliptica,* including a sample that appeared to be a putative *E. dalrympleana* × *elliptica* hybrid, clustered closely with the two subspecies of *E. dalrympleana* and *E. rubida* subsp. *barbigerorum*. When a test *splitstree* analysis was run without this hybrid sample in the dataset the remaining *E. elliptica* samples formed a more distinct cluster. Conversely, *E. rubida* subsp. *rubida,* with *E. canobolensis* clustered within it, formed a discreet cluster well removed from this cluster. The most genetically divergent population of *E. rubida* subsp. *rubida* from NW of Yass in the Southern Tablelands region was identified as putatively having experienced gene-flow with *E. mannifera* subsp. *mannifera,* which also occurs in the collection location. Additionally, a *E. viminalis* subsp. *viminalis* sample collected from Katoomba View, Jenolan was putatively identified as a *E. dalrympleana* × *viminalis* hybrid.

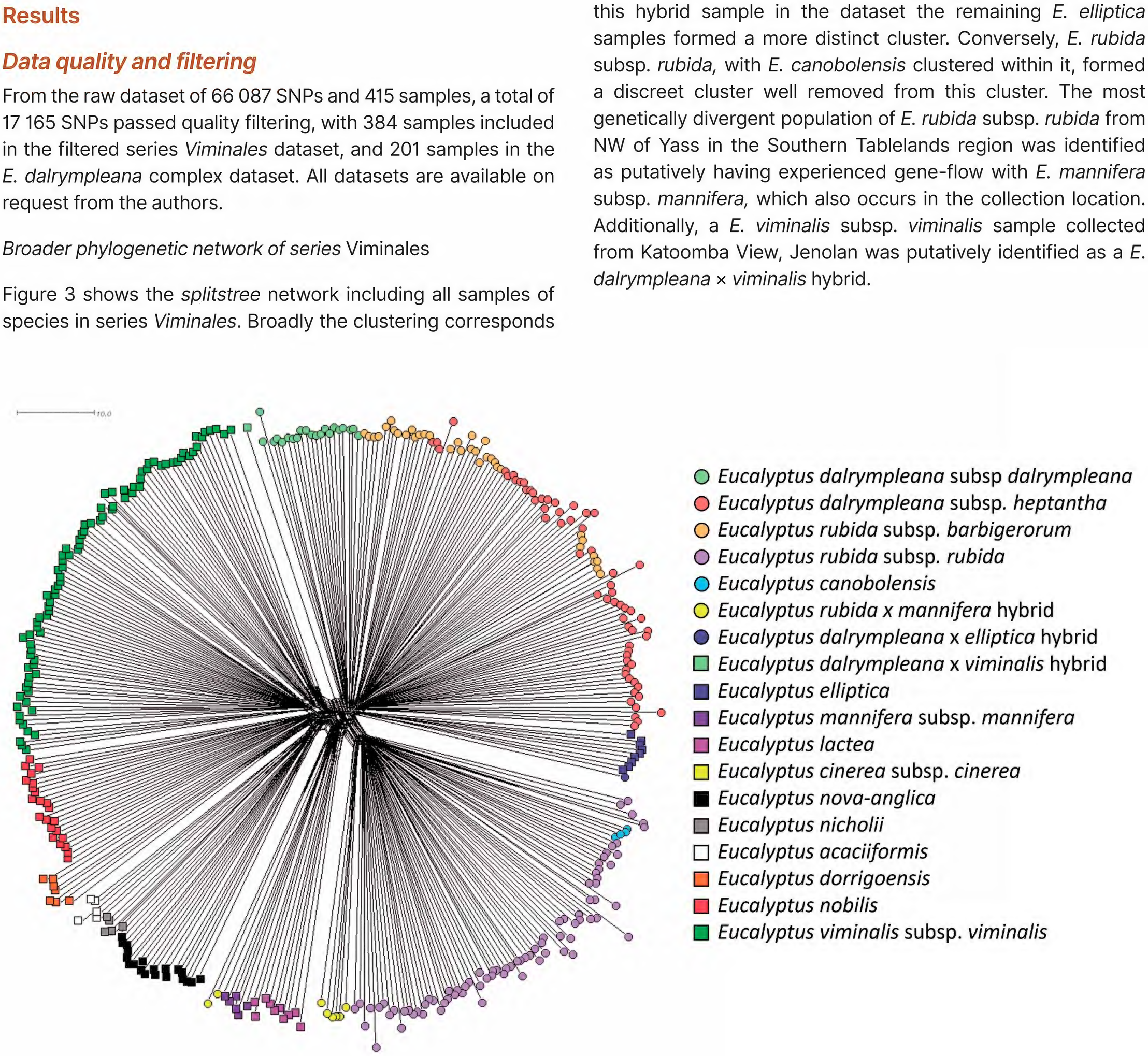

Figure 3. *SplitsTree* network of all *Eucalyptus* series *Viminales* species sampled for this study calculated using Euclidean genetic distances. Tip node colouration corresponds to species, with members of the *E. dalrympleana* complex indicated with circular node tips and all other taxa having square node tips.

Eucalyptus dalrympleana *complex analyses*

In the PCA of the *E. dalrympleana* complex (Fig. 4) PC1 explained ~8.4% of the variation in the data, and broadly separated the samples into three clusters; with the *E. rubida* subsp. *rubida* and *E. canobolensis* cluster being more distinct from the *E. dalrympleana* subsp. *dalrympleana*, and *E. dalrympleana* subsp. *heptantha* and *E. rubida* subsp. *barbigerorum* clusters than the latter were from one another. *Eucalyptus dalrympleana* subsp. *heptantha* and *E. rubida* subsp. *barbigerorum* showed none of the separation in the PCA that would be expected if there were distinct taxa. PC2 (~2% of variation explained) primarily separated the two *E. dalrympleana* s.l. clusters; however, several samples of *E. rubida* subsp. *barbigerorum* from Nundle State Forest and New England National Park and a single sample of *E. dalrympleana* subsp. *dalrympleana* from Hobby's Yard in the Central Tablelands were intermediate between the two *E. dalrympleana* subspecies. The populations of *E. rubida* subsp. *barbigerorum* from Nundle State Forest and New England National Park were noted as having a form resembling *E. dalympleana* subsp. *dalrympleana* in the field.

The results of the STRUCTURE analyses were congruent with those of the PCA (Fig. 5). In the two-cluster analysis *E. rubida* subsp. *rubida* and *E. canobolensis* were assigned to one cluster and *E. dalrympleana* subsp. *heptantha* and *E. rubida* subsp. *barbigerorum* were primarily assigned to the second. Meanwhile, *E. dalrympleana* subsp. *dalrympleana* was partially assigned to both clusters. When the cluster number was increased to three, *E. dalrympleana* subsp. *dalrympleana* was assigned to the third cluster, separating it from *E. dalrympleana* subsp. *heptantha* and *E. rubida* subsp. *barbigerorum*, with the samples of the latter from Nundle State Forest and New England NP showing partial assignment to both clusters. All tested values of K above three showed poor fit to the data, and so are not shown

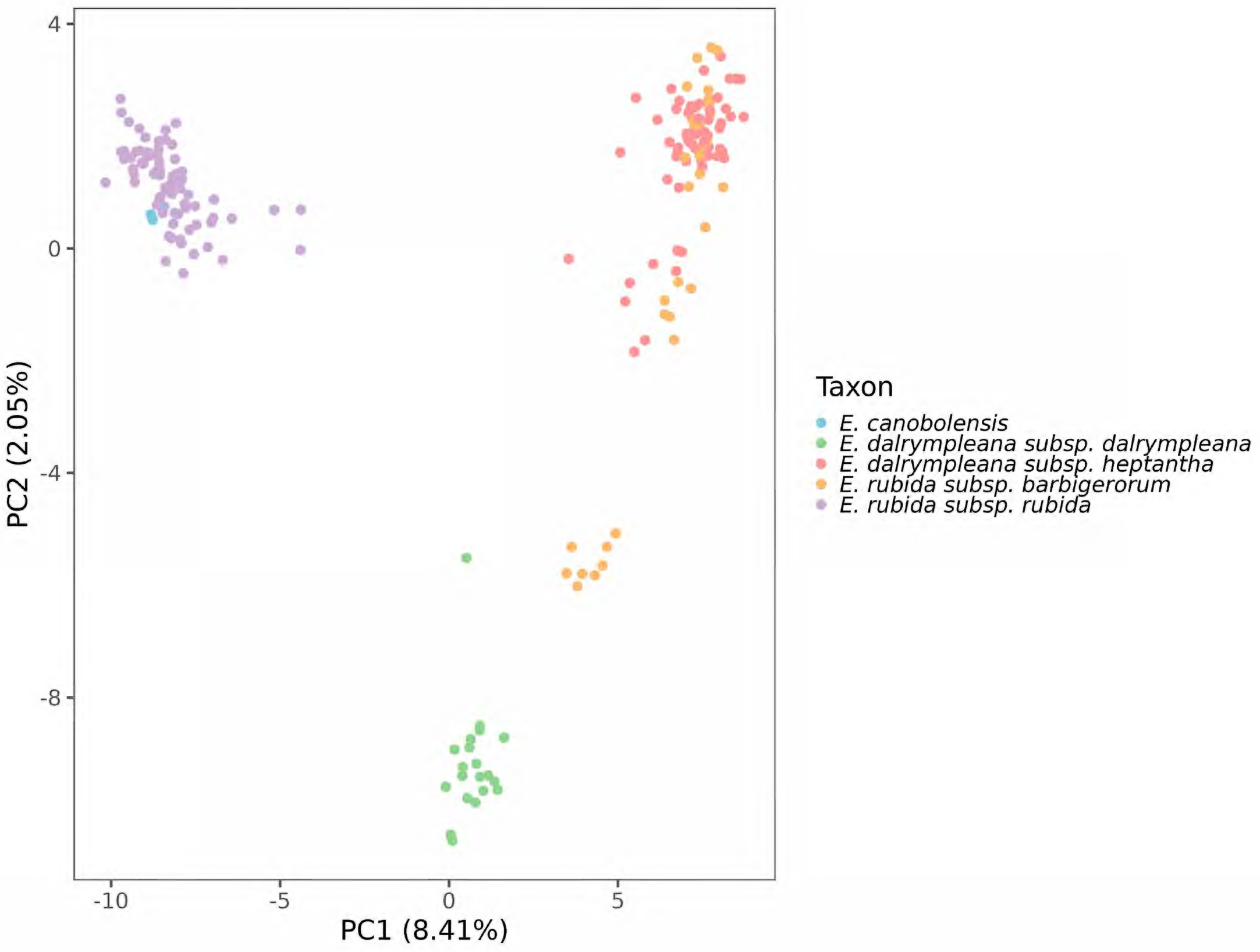

Figure 4. The first two axes of a principal component analysis of SNP data for members of the *E. dalrympleana* complex, with points representing genotyped individuals coloured to match their field identification. *Eucalyptus rubida* subsp. *rubida* and *E. canobolensis* cluster separately to both *E. dalrympleana* subspecies and *E. rubida* subsp. *barbigerorum* on axis one (~8.4% of variation), with *E. dalrympleana* subsp. *dalrympleana* separating from *E. dalrympleana* subsp. *heptantha* and *E. rubida* subsp. *barbigerorum* on axis 2 (~2 % of variation).

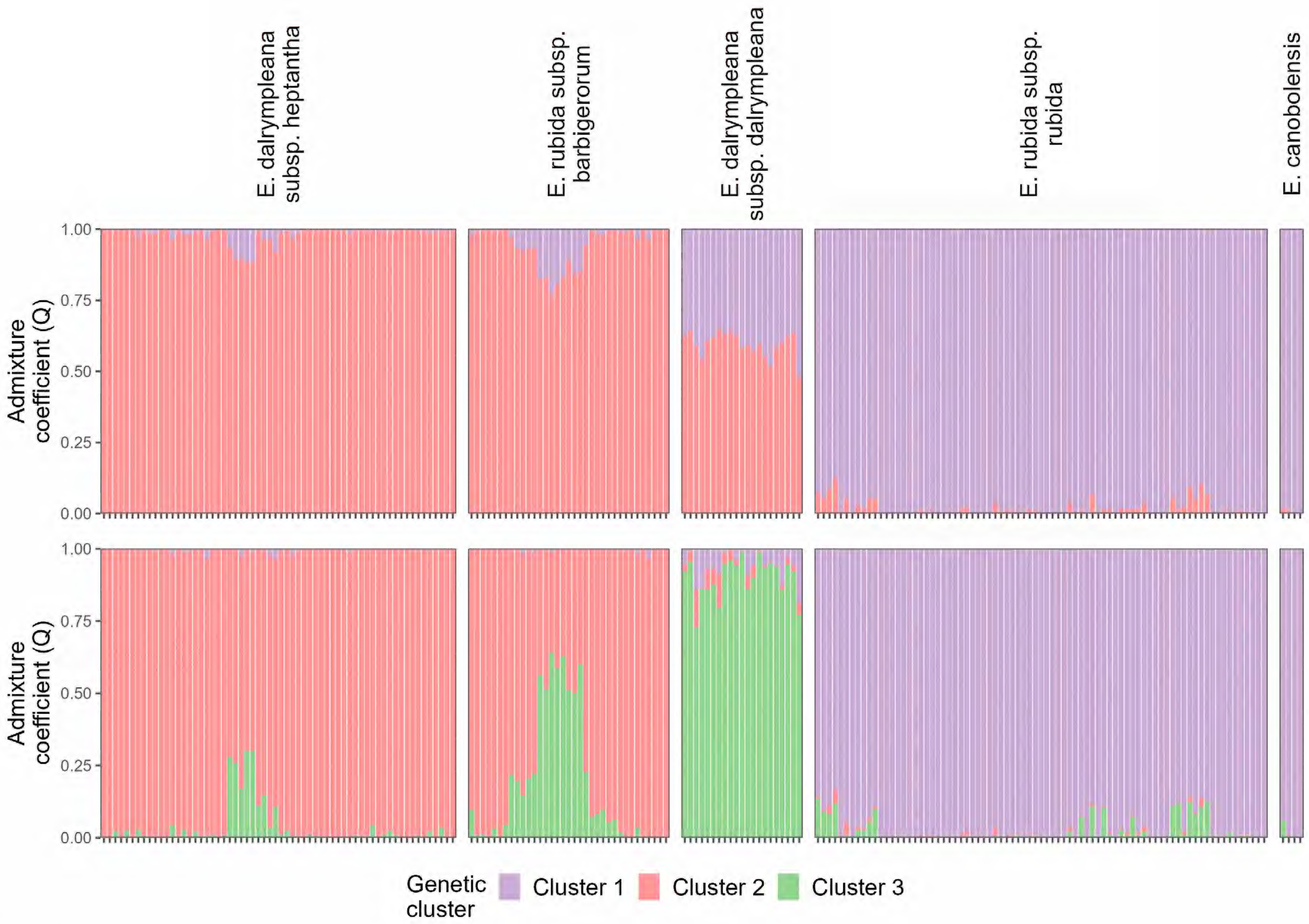

Figure 5. Bar plot summarising STRUCTURE analysis of the *Eucalyptus dalrympleana* complex, showing the two best performing values of K (2 and 3), each run with five replicates. Samples are grouped by existing species definitions, with clustering at both K= 2 and 3 showing *E. rubida* subsp. *barbigerorum* sharing a genetic cluster with *E. dalrympleana,* and *E. canobolensis* forming a single cluster with *E. rubida* subsp. *rubida*.

Discussion

Bar the close relationship between *E. mannifera* subsp. *mannifera* (subseries *Lanceolatae*) and members of subseries *Circulares*, the classification of series *Viminales* by Nicolle and Jones (2018) is broadly congruent with our findings. Our finding of a close relationship between *E. mannifera* subsp. *mannifera* and *E. cinerea* and *E. lactea* aligns with the topology of the phylogeny presented by Jones et al. (2016), although this relationship lacked statistical support in their analysis. Therefore, we suggest that the placement *of E. mannifera* in subser. *Lanceolatae* may need reconsideration to ensure subseries reflect evolutionary relatedness. Despite this, we find support for *E. lactea* being considered a distinct species rather than a subspecies of *E. mannifera* due to close relationship between *E. cinerea* and *E. mannifera* subsp. *mannifera*. Our phylogenetic network (Fig. 3) does not return the *E. dalrympleana* complex as a natural grouping to the exclusion of *E. elliptica*, however we hypothesis this is due to the inclusion of a *E. dalrympleana* × *elliptica* hybrid in our dataset and not a reflection of true evolutionary relatedness.

Based upon the genetic relationships presented in Figures 3, 4 and 5, we suggest that the distinctiveness of *E. canobolensis* is significantly overemphasised by its recognition as a distinct species. Contrary to the hypothesis put forward by Hunter (1998) based upon morphology, the genetic evidence shows with certainty that the nearest relatives of the Mount Canobolas population are the surrounding *E. rubida* subsp. *rubida* populations (Fig. 5). However, the morphological distinctiveness and unique habitat of this population has long been recognised (Maiden 1917; Chappill and Ladiges 1996; Hunter 1998) and reciprocal monophyly is not a necessary, nor even expected, evolutionary pattern for subspecies (Patten 2015). Therefore, in the absence of more detailed morphological and genetic study, we believe it appropriate to take the conservative approach of maintaining this taxon at the subspecies level as *E. rubida* subsp. *canobolensis* per Hill and Johnson (1991). This change does not impact the conservation assessment of the population which remains under threat (Phillips and Zimmer 2022), however as a subspecies of an otherwise non-threatened species, this may allow for different management techniques such as genetic supplementation to assist in adaptation to climate change that threaten to send the population to extinction (Bragg *et al.* 2022).

Our sampling of *E. rubida* subsp. *barbigerorum* includes samples from both the type population north-west of Wandsworth and from additional sites that were assessed by Hunter (2017) as being very likely to be genetically pure/lack introgression from E. *dalrympleana* subsp. *heptantha*. Despite this, all *E. rubida* subsp. *barbigerorum* samples are clearly more closely related to E. *dalrympleana* than to *Eucalyptus rubida* subsp. *rubida*. This matches the field observations of Hunter (2017) and warrants transferring this taxon out of *E. rubida* and into *E. dalrympleana*.

There are two approaches that could be taken with this transfer, either erecting a new subspecies within *E. dalrympleana* to accommodate these populations or to only recognise a single taxon in the *E. dalrympleana* complex in the New England Tablelands of NSW. Given the very low genetic divergence observed in this study, the widespread morphological intergradation observed during systematic field surveys of the taxon, and the high amount of phenotypic plasticity in the morphological traits used to delimit *E. rubida* subsp. *barbigerorum* and *E. dalrympleana* subsp. *heptantha* (Hunter 2017) (namely the number of flowers per inflorescences and extent of rough bark on the trunk) in related taxa, we conclude that *E. rubida* subsp. *barbigerorum* should be considered a taxonomic synonym of *E. dalrympleana* subsp. *heptantha*.

This does raise questions around the distinctness of the two *E. dalrympleana* subspecies in NSW, as they are differentiated morphologically by the number of flowers in each inflorescence, a distinction that is weakened by the synonymising of the three flowered *E. rubida* subsp. *barbigerorum* with the seven flowered *E. dalrympleana* subsp. *heptantha*. Additionally, the identification of populations genetically intermediate between *E. dalrympleana* subsp. *heptantha* and *E. dalrympleana* subsp. *dalrympleana* in the eastern parts of the Northern Tablelands complicates any taxonomic resolutions. Given the level of genetic divergence between most populations of *E. dalrympleana* subsp. *heptantha* s.l. in the Northern Tablelands, and those of *E. dalrympleana* subsp. *dalrympleana* in the Central and Southern Tablelands of NSW we support the recognition of these subspecies based on genetic divergence and geography at this point. However, further work is needed to investigate reliable morphological features that differentiate these subspecies and the identity of *E. dalrympleana* populations on the eastern edge of the Northern Tablelands which show some genetic affinity to southern populations of the species.

Overall, we believe our study highlights the power of using population level sampling and population genetic analytical approaches in resolving the relationships and taxonomy of closely related eucalypt taxa, which has long been complicated by their propensity to hybridise and high variability across species ranges.

Taxonomy

Eucalyptus dalrympleana Maiden, *Proc. Linn. Soc. New South Wales* 23: 164 (1898). *Type*: New South Wales: Yarrangobilly, Peppercorn Plain, January 1920, *W.A.W. de Beuzeville* 1, 2, 3 (syn: NSW).

Notes: No samples of *E. dalrympleana* from outside NSW were investigated in this genetic study so the recent taxonomic changes proposed by Nicolle (2022) are not tested here, but should be considered in future studies.

Eucalyptus dalrympleana subsp. ***dalrympleana***

Distribution: Widespread in the Central and Southern Tablelands of New South Wales through eastern Victoria, with outlying populations in the Mount Lofty Ranges of South Australia (Fig. 6).

Notes: Populations genetically intermediate between this subspecies and *E. dalrympleana* subsp. *heptantha* appear to exist on the eastern edge of the Northern Tablelands, with further morphological study needed to investigate where these populations fit. Here these populations are treated under *E. dalrympleana* subsp. *heptantha*.

Eucalyptus dalrympleana subsp. ***heptantha*** L.A.S.Johnson, *Contr. New South Wales Natl Herb.* 3: 110 (1962). *Type*: New South Wales: Wandsworth to Moredun Ck, 3000 ft, 23 May 1957, *L.A.S.Johnson* (holo: NSW 41849; iso: FRI, K).

Eucalyptus rubida subsp. *barbigerorum* L.A.S.Johnson & K.D.Hill, *Telopea* 4: 240 (1991). *Type*: New South Wales: Northern Tablelands: 14.1 km from Wandsworth towards Tingha, 29 Aug. 1986, *K.D.Hill 2117* (holo: NSW200439; iso: BRI, CANB, CBG, MEL).

Distribution: Widespread in the Northern Tablelands of New South Wales and adjacent areas of southern Queensland (Fig. 6).

E. dalrympleana subsp. ***lutruwita*** D.Nicolle, *Native Eucalypts Vict. & Tasman., S.-E. Austral.* 180–181 (2023). *Type:* Tasmania: Lakes Highway [Highland Lakes Rd], 26.4 km NW of Bothwell, 4 June 1979, *A.M.Gray 374* (holo: AD 97943538; iso: CANB, HO, MEL, NSW, PERTH).

Distribution: Widespread across central and eastern Tasmania (Fig. 6).

E. dalrympleana subsp. ***poliophylla*** D.Nicolle, *Native Eucalypts Vict. & Tasman., S.-E. Austral.* 182–183 (2023). *Type:* Victoria: Howmans Gap Alpine Resort, c. 4 km N from Falls Creek Village, 12 January 2001, *N.GWalsh 5293* (holo: MEL 2104852; iso: CANB, NSW).

Distribution: Restricted to higher elevation (>1200 m) regions of eastern Victoria (Fig. 6).

Eucalyptus rubida H.Deane & Maiden, *Proc. Linn. Soc. New South Wales* 24: 456 (1899). *Type:* New South Wales: Jindabyne, Jan. 1898, *J.H.Maiden s.n.* (lecto: NSW325637, NSW325636), first step lectotypification (restricting the type to a single collection at NSW, but mounted on two sheets) designated by J.H.Maiden, Crit. Rev. genus Eucalyptus 3(6) 110–122 (1916).

Eucalyptus rubida subsp. ***rubida***

Eucalyptus *rubida* subsp. *septemflora* L.A.S.Johnson & K.D.Hill, *Telopea* 4: 241 (1991). *Type*: Victoria: 3 km N of Mt Beauty North on Wodonga road, 20 Feb. 1986, *K.D.Hill 1430 & L.A.S.Johnson* (holo: NSW205444).

Distribution: Widespread in hilly and tableland country from the Central and Southern Tablelands of New South Wales, eastern Victoria, and Tasmania (Fig. 7).

Eucalyptus rubida subsp. ***canobolensis*** L.A.S.Johnson & K.D.Hill, *Telopea* 4: 239 (1991). *Eucalyptus canobolensis* (L.A.S.Johnson & K.D.Hill) J.T.Hunter, *Telopea* 8: 157 (1998). *Type*: New South Wales: Central Tablelands: Mt Canobolas, Orange, Jan. 1908, *J.L. Boorman s.n.* (holo: NSW325550).

Distribution: Endemic to higher elevations on Mount Canobolas, Orange, New South Wales (Fig. 7)

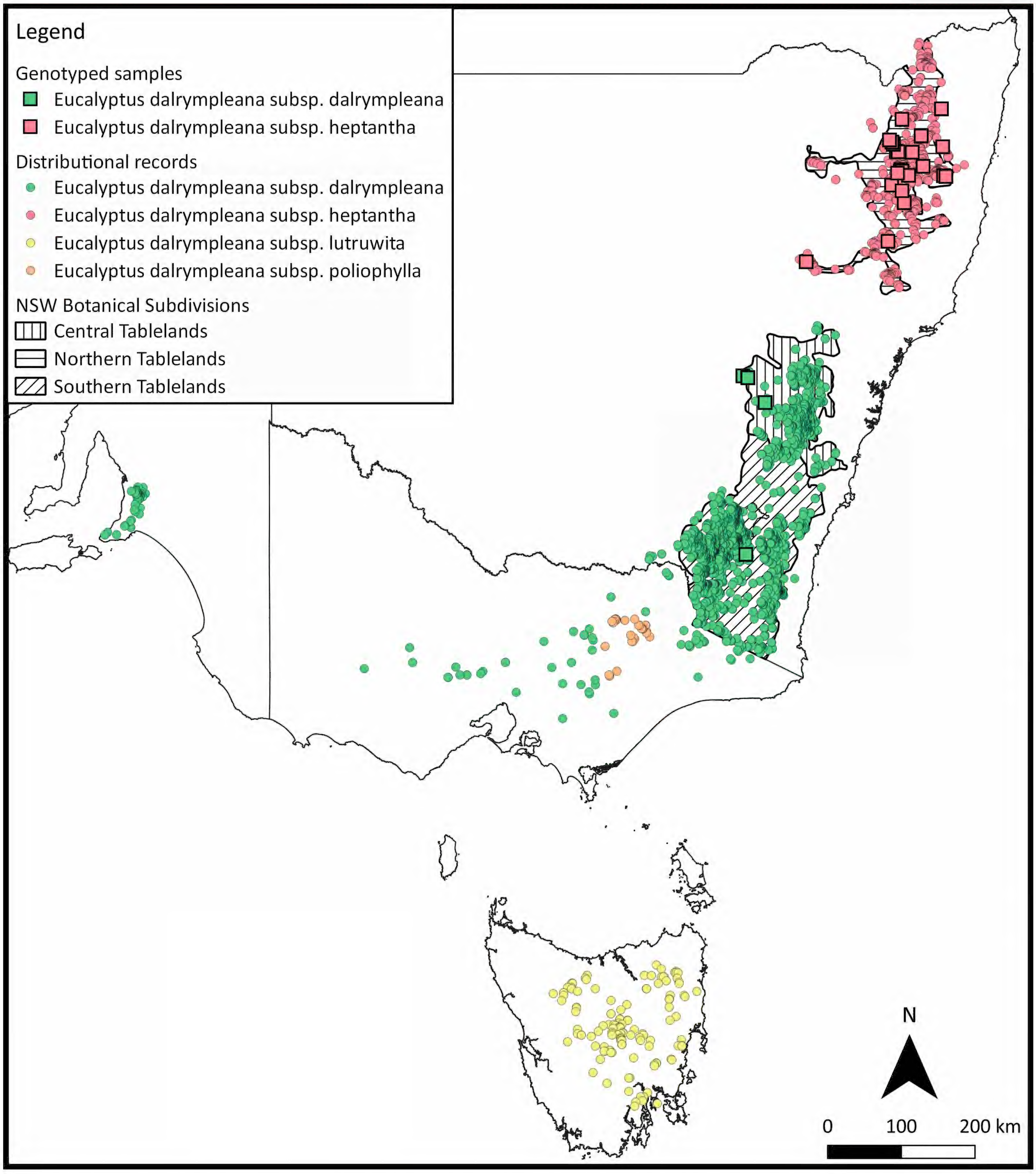

Figure 6. The distribution of the subspecies of *Eucalyptus dalrympleana* based upon the findings of our genetic study and the most recent taxonomic literature on the species. Genotyped samples are shown on the map using large squares and coloured by the subspecies assignment best supported by genetic data. Atlas of Living Australia (2024) records are shown with circular points and coloured by subspecies assignment based upon the understanding of their distributions from the literature and our genetic data. Also shown are the botanical regions of New South Wales in which the species is considered to naturally occur.

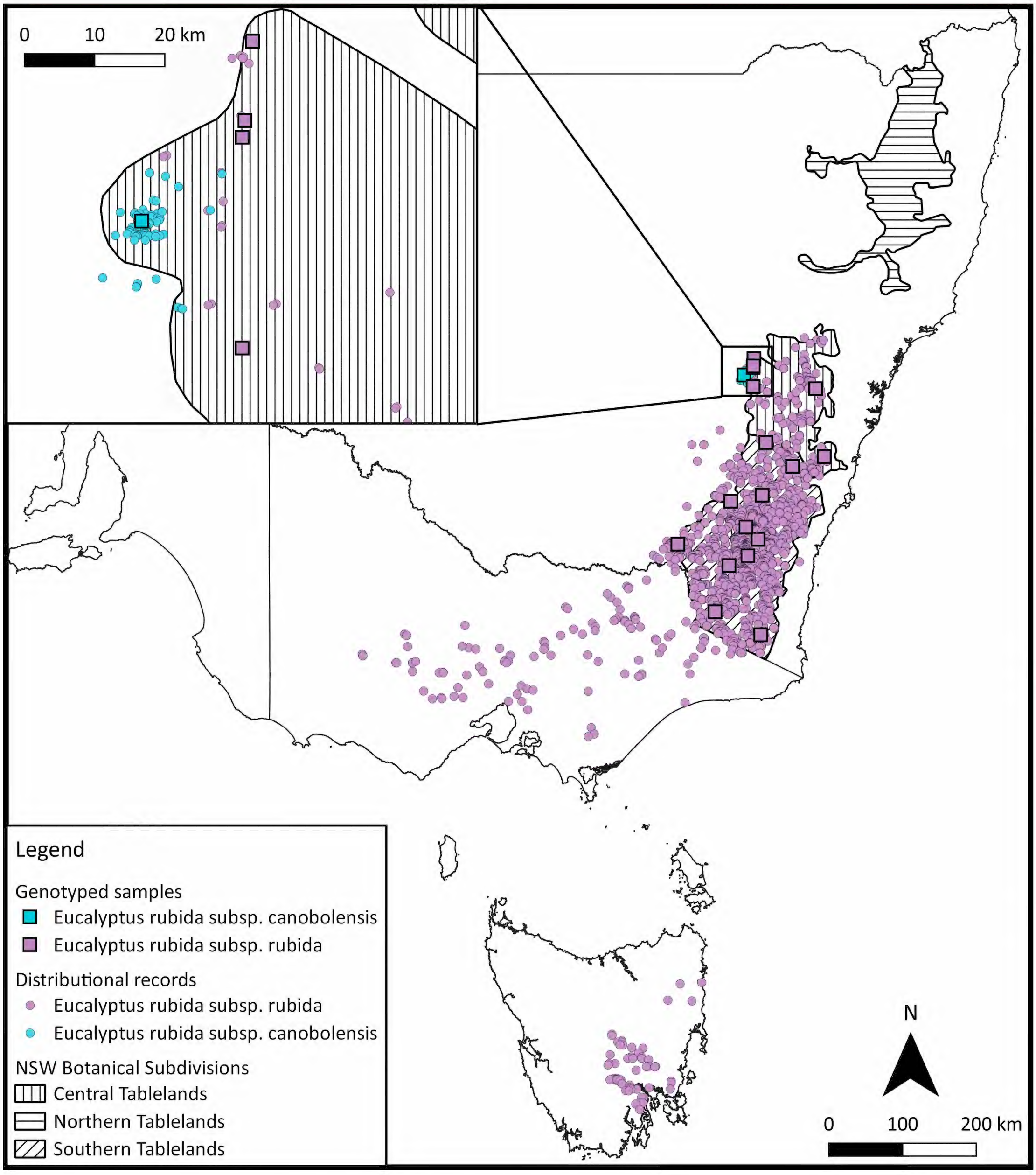

Figure 7. The distribution of the subspecies of *Eucalyptus rubida* based upon the findings of our genetic study and the most recent taxonomic literature on the species. Genotyped samples are shown on the map using large squares and coloured by the subspecies assignment best supported by genetic data. Atlas of Living Australia (2024) records are shown with circular points and coloured by subspecies assignment based upon the understanding of their distributions from the literature and our genetic data. Also shown are the botanical regions of New South Wales in which the species is considered to naturally occur.

References

Atlas of Living Australia (2024) Atlas of Living Australia. Available at URL [Accessed 5 April 2024].

Bragg, JG, van der Merwe, M, Yap, J-YS, Borevitz, J, Rossetto, M (2022) Plant collections for conservation and restoration: Can they be adapted and adaptable? *Molecular Ecology Resources* **22**, 2171–2182. DOI

Brooker, MIH, Slee, AV, Connors, JR, Duffy, S, West, J (2015) EUCLID: Eucalypts of Australia. Available at URL

Chappill, J, Ladiges, P (1996) Phylogenetic analysis of *Eucalyptus* informal subgenus *Symphyomyrtus* section *Maidenaria*. *Australian Systematic Botany* **9**, 71–93. DOI

Council of Heads of Australasian Herbaria (2016) *Australian Plant Census*, IBIS database. Centre for Australian National Biodiversity Research, Australian Government, Canberra.

Deane, H, Maiden, JH (1899) Observations on the eucalypts of New South Wales. Part V. *Proceedings of the Linnean Society of New South Wales* **24**, 448–471.

Earl, DA, vonHoldt, BM (2011) STRUCTURE HARVESTER: a website and program for visualizing STRUCTURE output and implementing the Evanno method. *Conservation Genetics Resources* **4**, 359–361. DOI

Evanno, G, Regnaut, S, Goudet, J (2005) Detecting the number of clusters of individuals using the software STRUCTURE: a simulation study. *Molecular Ecology* **14**, 2611–2620. DOI

Gruber, B, Unmack, PJ, Berry, OF, Georges, A (2018) *DARTR*: An R package to facilitate analysis of SNP data generated from reduced representation genome sequencing. *Molecular Ecology Resources* **18**, 691–699. DOI

Hill, KD, Johnson, LAS (1991) Systematic studies in the eucalypts – 3. New taxa and combinations in *Eucalyptus* (Myrtaceae). *Telopea* **4**, 223–267. URL

Hunter, JT (1998) *Eucalyptus canobolensis* (Myrtaceae), a new combination for a former subspecies of *Eucalyptus rubida*. *Telopea* **8**, 157–159. URL

Hunter, JT (2017) Monitoring of *Eucalyptus rubida* subsp. *barbigerorum*. Document Prepared by. Dr John T. Hunter. Hewlett Hunter Pty Ltd. For 'Saving Our Species' PDF

Huson, DH, Bryant, D (2006) Application of phylogenetic networks in evolutionary studies. *Molecular Biology and Evolution* **23**, 254–267. DOI

Jombart, T (2008) adegenet: a R package for the multivariate analysis of genetic markers. *Bioinformatics* **24**, 1403–1405.

Jombart, T, Ahmed, I (2011) adegenet 1.3-1: new tools for the analysis of genome-wide SNP data. *Bioinformatics* **27**, 3070–3071. DOI

Jones, R, Nicolle, D, Steane, D, Vaillancourt, R, Potts, B (2016) High density, genome-wide markers and intra-specific replication yield an unprecedented phylogenetic reconstruction of a globally significant, speciose lineage of *Eucalyptus*. *Molecular Phylogenetics and Evolution* **105**, 63–85. DOI

Kilian, A, Wenzl, P, Huttner, E, Carling, J, Xia, L, Blois, H, Caig, V, Heller-Uszynska, K, Jaccoud, D, Hopper, C, Aschenbrenner-Kilian, M, Evers, M, Peng, K, Cayla, C, Hok, P, Uszynski, G (2012) Diversity Arrays Technology: a generic genome profiling technology on open platforms. *Data Production and Analysis in Population Genomics* **888**, 67–89. DOI

Maiden, JH (1917) *A critical revision of the genus* Eucalyptus *Vol. III*. (Government Printer: Sydney)

Maiden, JH, Flockton, M (1922) *The forest flora of New South Wales*. (W.A. Gullick: Sydney)

Nicolle, D (2022) *Native Eucalypts of Victoria and Tasmania, South-eastern Australia*. (Bloomings Books: Adelaide)

Nicolle, D (2024) Classification of the eucalypts (*Angophora*, *Corymbia* and *Eucalyptus*) Version 7. Available at PDF

Nicolle, D, Jones, R (2018) A revised classification for the predominantly eastern Australian *Eucalyptus* subgenus *Symphyomyrtus* sections *Maidenaria*, *Exsertaria*, *Latoangulatae* and related smaller sections (Myrtaceae). *Telopea* **21**, 129–145. DOI

Patten, MA (2015) Subspecies and the philosophy of science. *The Auk* **132**, 481–485. DOI

Phillips, GP, Zimmer, H (2022) Conservation assessment of *Eucalyptus canobolensis* (L.A.S.Johnson & K.D.Hill) J.T.Hunter. NSW Threatened Species Scientific Committee.

Pritchard, JK, Stephens, M, Donnelly, P (2000) Inference of population structure using multilocus genotype data. *Genetics* **155**, 945–959. DOI

R Development Core Team (2016) *R: A language and environment for statistical computing*. (R Foundation for Statistical Computing: Vienna, Austria)

Rossetto, M, Bragg, J, Kilian, A, McPherson, H, van der Merwe, M, Wilson, PD (2019) Restore and Renew: a genomics-era framework for species provenance delimitation. *Restoration Ecology* **27**, 538–548. DOI

Sansaloni, C, Petroli, C, Jaccoud, D, Carling, J, Detering, F, Grattapaglia, D, Kilian, A (2011) Diversity Arrays Technology (DArT) and next-generation sequencing combined: genome-wide, high throughput, highly informative genotyping for molecular breeding of *Eucalyptus*. *BMC Proceedings* **5**, P54. DOI

Sansaloni, CP, Petroli, CD, Carling, J, Hudson, CJ, Steane, DA, Myburg, AA, Grattapaglia, D, Vaillancourt, RE, Kilian, A (2010) A high-density Diversity Arrays Technology (DArT) microarray for genome-wide genotyping in *Eucalyptus*. *Plant Methods* **6**, 16. DOI

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The identity and taxonomic status of the rare *Angophora*/*Eucalyptus exul* (Myrtaceae) from the Northern Tablelands of New South Wales

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Abstract

Since its description in 1997, the taxonomic status of *Angophora*/*Eucalyptus exul* has been contentious, partly due to the uncertain identity of the type specimen, which was collected in 1996 from Gibraltar Rock on the Northern Tablelands of New South Wales. Through careful observations at the type location in association with some luck, we have been able to positively identify the type tree in the field. This tree is regarded by us to be a hybrid individual of two other *Angophora* species that are common at the site, *A. floribunda*/*E. florida* and *A.*/*E. leiocarpa*. On this basis, we recommend that *A.*/*E. exul* be removed from New South Wales threatened species legislation.

Introduction

Angophora exul K.D.Hill was described in 1997 from a 'single small stand on Gibraltar Rock, west of Tenterfield' on the New England Tableland in New South Wales (Hill 1997). The new species was compared to other narrow-leaved, rough-barked *Angophora* species such as *A. bakeri* E.C.Hall, *A. crassifolia* (G.J.Leach) L.A.S.Johnson & K.D.Hill, *A. paludosa* (G.J.Leach) K.R.Thiele & Ladiges, and *A. inopina* K.D.Hill (Hill 1997), none of which are known from the Northern Tablelands in NSW. In addition to the type specimen (*K.D. Hill 4788, L.C. Stanberg & K.L. Wilson*, Figure 1), Hill (1997) cited another specimen from the same locality (*Roberts s.n.*, 29 Jul 1992), as well as attributing another specimen from the same locality as an *A. floribunda* – *A. exul* intergrade (*K.D. Hill 4785, L.C. Stanberg & K.L. Wilson*).

Subsequent to its description, the taxonomic status of *A. exul* has been contentious. Slee *et al.* (2015) included *A. exul* in *A. bakeri* subsp. *bakeri*, despite it being geographically quite isolated from populations otherwise attributable to *A. bakeri*.

Through careful observations at the type location, we have been able to positively identify the type tree in the field. In March 2021, one of us (DN) photographed two trees at the type location that matched the type description and specimens of *A. exul*. We were later able to match the photographs of one of these trees with a photograph of the type tree taken by Karen Wilson at the time the type was gathered in 1996 by Ken Hill, who is in the photo with the tree. Luckily, the site has not been burnt by wildfire in modern history (NSW NPWS 2024), which allowed the tree photographed by Wilson in 1996 to be identified and matched with our 2021 photographs (Fig. 2).

We regarded all angophora taxa are best included in *Eucalyptus* L'Her., within *E.* subg. *Angophora* (following the recommendations of Nicolle *et al.* 2024). To avoid confusion, we have used dual names for angophora taxa herein, using both their traditional binomial

Nicolle D, Phillips GP (2024) The identity and taxonomic status of the rare *Angophora*/*Eucalyptus exul* (Myrtaceae) from the Northern Tablelands of New South Wales. *Telopea* 27: 197–201.
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within genus *Angophora* Cav., and our preferred binomial within genus *Eucalyptus*, following Brooker (2000) and Nicolle (2024) and using the recommended genus-level classification of Nicolle *et al*. (2024).

Fig. 1. Holotype of *Angophora exul* (NSW 398589).

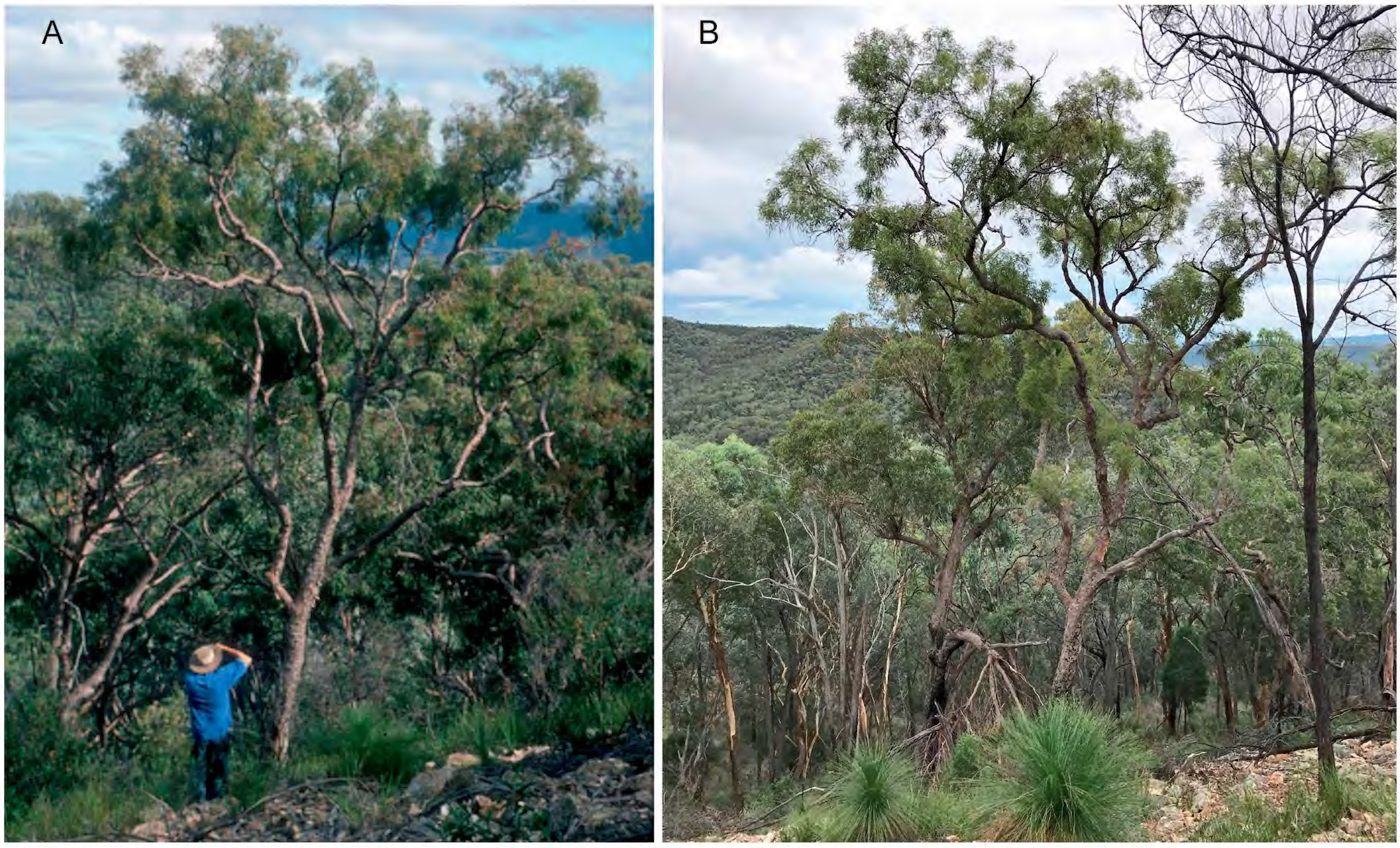

Fig. 2. The type tree of *Angophora exul* (*Hill 4788, L.C. Stanberg & K.L. Wilson*). A. Photographed by Karen Wilson on the 22nd February 1996, on the day that the type specimens were gathered by Ken Hill, who is pictured with the tree. B. The same individual tree photographed by Dean Nicolle 25 years later on the 17th of March 2021 (*D.Nicolle 8065*).

Discussion

The type location of *Angophora/Eucalyptus exul* (K.D.Hill) Brooker was cited as 'Gibraltar Rock, W of Tenterfield' where it was described as 'occurring only on open scree on a ridge of acid volcanic outcrops' (Hill 1997). The type site, located off Silent Grove Road at 29°05'17"S, 151°42'30"E, consists of remnant woodland dominated by *Angophora floribunda* (Sm.) Sweet / *Eucalyptus florida* Brooker, *E. albens* Benth., *E. caleyi* Maiden subsp. *caleyi, E. dealbata* A.Cunn. ex Schauer and *E. laevopinea* R.T.Baker, and with scattered trees of *A. leiocarpa* (L.A.S.Johnson ex G.J.Leach) K.R.Thiele & Ladiges / *E. leiocarpa* (L.A.S.Johnson ex G.J.Leach) Brooker. *Angophora floribunda*/*Eucalyptus florida* and *A./E. leiocarpa* are easily distinguished at the site, with the former being fully rough-barked and having relatively broad adult leaves, and the latter being completely smooth-barked and having relatively narrow adult leaves. In addition to these species, there are two individual trees at the site which are clearly hybrids of *A. floribunda*/*E. florida* × *A./E. leiocarpa*, having morphology that is intermediate between these two species, which is especially evident in the field due to their intermediate bark morphology and adult leaf width.

The type material of *A./E. exul* matches one of the two *A. floribunda*/*E. florida* × *A./E. leiocarpa* hybrid individuals at the site. While this is only partly evident in the plant material on the type specimen sheets, the accompanying photograph of the type tree is more telling, and confirms with certainty that the type tree of *A./E. exul* is one of the two hybrid individuals identified on the site by one of us (DN) in March 2021.

We conclude that only two *Angophora*/*E.* subg. *Angophora* species occur at Gibraltar Rock, viz. the rough-barked, relatively broad-leaved, rib-fruited *A. floribunda*/*E. florida*, and the smooth-barked, relatively narrow-leaved, more-or-less smooth-fruited *A./E. leiocarpa*. Rare hybrids between these two species also occur at the site and are distinctive in their intermediate bark and foliage characteristics. The type tree of *A./E. exul* is representative of one of these rare hybrids, as is the other specimen cited by Hill (1997) as *A. exul* (*Roberts s.n.*, 29 Jul 1992, see Fig. 3).

We regard the specimen cited by Hill (1997) as an *A. floribunda* – *A. exul* intergrade (*K.D. Hill 4785, L.C. K.L. Stanberg & Wilson*) as being typical *A. floribunda*/*E. florida* (Fig. 3).

Three other specimens at NSW have been determined by their original collectors to be *A. exul*. These are *Johnstone 3494 & Catelotti,* which was gathered approximately 260 metres south-west of the type tree of *A./E. exul; Copeland 3495, Gilmour & Wall,* which was gathered approximately 1.6 km north-west from the type tree of *A./E. exul,* and *Copeland 3548 & Telford*, which was gathered approximately 1.6 km north-north-west from the type tree of *A./E. exul*. Based on their intermediate bark morphology (as described on the label data), and their intermediate but variable foliage and bud/fruit morphology, we regard these three specimens as second- or later-generation backcrosses of the hybrid to *A. floribunda*/*E. florida*.

Fig. 3. Specimens cited by Hill (1997). A. *Roberts s.n.*, cited as *Angophora exul* (the only cited specimen of this species other than the type); B. *Hill 4785, Stanberg & Wilson*, cited as an *A. floribunda* – *A. exul* intergrade. We regard these two specimens as *A. floribunda*/*E. florida* × *A.*/*E. leiocarpa* (A) and *A. floribunda*/*E. florida* (B) respectively.

Another specimen at NSW has been determined by their original collectors to be *'Angophora exul* × *floribunda'* (*Johnstone 3436, Errington & Cardwell,* gathered within 50 metres of the type tree of *A.*/*E. exul*). Based on its description (on the label data) and morphology, we also regard this specimen to be a second- or later-generation backcross of the hybrid to *A. floribunda*/*E. florida*.

A recent genetic study of the angophoras (Rutherford *et al.* 2020) identified numerous hybrids between species in the group, including probable hybrids between *A. floribunda*/*E. florida* and *A.*/*E. leiocarpa* at Tooloom (north-east of Tenterfield on the Northern Tablelands of NSW) and at Tarong (east of the Bunya Mountains in Qld). Unfortunately, the Rutherford *et al.* (2020) study did not include any material attributable to *A.*/*E. exul* nor include any individuals from the Gibraltar Rock area (the type location of *A.*/*E. exul*).

Angophora exul is currently listed as Endangered on the New South Wales *Biodiversity Conservation Act 2016*. Given the conclusion reached here that *A.*/*E. exul* represents a hybrid, its eligibility to remain listed as a threatened species should also be reviewed. Hybrids are not accommodated in the definition of a species on the *Biodiversity Conservation Act 2016*. This makes *A.*/*E. exul* no longer eligible to be listed as a threatened species in New South Wales, and in this regard the species should be considered for removal from conservation legislation.

Taxonomy

Eucalyptus* × *exul (K.D.Hill) Brooker, *Austral. Syst. Bot* 13: 136 (2000).

Basionym: *Angophora exul* K.D.Hill, *Telopea* 7(2): 100 (1997). *Type*: New South Wales: North Western Slopes: Gibraltar Rock, W of Tenterfield, 22 Feb 1996, *K.D.Hill 4788, L.C.Stanberg & K.L.Wilson* (holo: NSW 398589; iso: AD, BRI, CANB, K, MEL, MO, NY, P).

[= *Eucalyptus florida* × *E. leiocarpa*]

Specimens examined: New South Wales: Northern Tablelands: Rock of Gibraltar 31 km W of Tenterfield, 29 Jul 1992, *Roberts s.n.* (NSW); east of Rock of Gibraltar off Silent Grove Rd, 29°05'17"S, 151°42'30"E, 17 Mar 2021, *D.Nicolle 8065* (photograph only).

Acknowledgments

We are grateful to Sarah Caldwell from Mole Station Native Nursery for local advice and assistance in accessing the type locality at Gibraltar Rock. We also thank Karen Wilson (National Herbarium of New South Wales) for discussions regarding the photography at the type location in 1996, and for providing the image of the type tree.

References

Brooker MIH (2000) A new classification of the genus *Eucalyptus* L'Hér. (Myrtaceae). *Australian Systematic Botany* **13**: 79–148. DOI

Hill KD (1997) New species in *Angophora* and *Eucalyptus* (Myrtaceae) from New South Wales. *Telopea* **7**: 97–109. DOI

Nicolle D (2024) Transfer of residual species and subspecies from *Angophora* and *Corymbia* to *Eucalyptus* (Myrtaceae). *Swainsona* **38**: 125–126. PDF

Nicolle D, Ritter MK, Jones RC, Phillips GP, French ME, Cumming R, Bell SAJ (2024) The genus problem - *Eucalyptus* as a model system for minimising taxonomic disruption. *Taxon* **73**: (online early) DOI

NSW NPWS (National Parks and Wildlife Service) (2024) *NSW Fire History – Wildfires and Prescribed Burns* [spatial data set]. Accessed using ArcGIS 10.8.2 for desktop, Redlands, California, USA. Esri Inc. 1999–2021.

Rutherford S, Wan JSH, Cohen JM, Benson D, Rossetto M (2020) Looks can be deceiving: speciation dynamics of co-distributed *Angophora* (Myrtaceae) species in a varying landscape. *Evolution* **75**: 310–329. DOI

Slee AV, Brooker MIH, Duffy SM, JG West (2015) *Euclid, Eucalypts of Australia*, Fourth Edition. URL

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Pultenaea rubescens (Fabaceae: Mirbelieae), a new species from north-eastern New South Wales

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Abstract

Pultenaea rubescens R.L.Barrett, Clugston & Jobson (Fabaceae, Faboideae, Mirbelieae) is described as a new species allied to *P. parrisiae* J.D.Briggs & Crisp. It is endemic to the Northern Tablelands and North Coast Districts, New South Wales, Australia. A discussion of its habitat and conservation status is provided, along with an identification key and photographs.

Introduction

Paul Rossington collected what he considered to be a new species of *Pultenaea* Sm. near Carrai, on the eastern fall of the New England Tableland, south-east of Armidale, New South Wales, in January 2022. The specimen was sent to NSW and identified as allied to *P. parrisiae* J.D.Briggs & Crisp by J. Clugston but noted to be disjunct from known populations of that species by 700 km (see Briggs & Crisp 1994; Figure 1). Further searching of specimens at NE and NSW identified one additional collection from Werrikimbe National Park, collected by Lachlan Copeland in 2010. Once it was recognised as a distinct taxon, dedicated surveys of suitable habitat, particularly in the Carrai State Conservation Area and Carrai National Park, resulted in additional collections being made from the Carrai and Werrikimbe areas, with all new populations being relatively close to known locations.

No other specimens have been located, meaning that no material was available for the revision of de Kok and West (2004), and it joins a growing number of new species to be recognised in the genus in recent years (Renner *et al*. 2022; Telford *et al*. 2022; Barrett *et al*. 2024a). Phylogenomic data support the placement of this entity as sister to *P. parrisiae* (Clugston *et al*., unpubl. data). This data places the entity in the core of *Pultenaea*, a genus that has now been re-circumscribed (Barrett *et al*. 2024b; see also Orthia *et al*. 2005 and Barrett *et al*. 2021 for further discussion).

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Figure 1. Distribution of *Pultenaea rubescens* (Red dots); *P. paleacea* (Blue dots) *P. elusa* (Orange dots) and *P. parrisiae* (Green dots). Adapted from data in the Atlas of Living Australia, October 2024.

Briggs & Crisp (1994) recognised *P. parrisiae* subsp. *parrisiae* and *P. parrisiae* subsp. *elusa* Briggs & Crisp. de Kok & West (2004) proposed elevating the latter subspecies to species rank, but did not validate the new combination and status, a matter corrected by Barrett *et al*. (2021). Morphological examination and comparison of *P. elusa* (J.D.Briggs & Crisp) R.L.Barrett & Clugston, *P. myrtoides* A.Cunn. ex Benth., *P. paleacea* Willd., and *P. parrisiae* at NSW found a number of consistent differences to specimens collected near Carrai and Werrikimbe National Park which we here recognise as a distinct species, *Pultenaea rubescens* R.L.Barrett, Clugston & Jobson.

Materials and Methods

The following description is based on examination of herbarium specimens at NSW. Type specimens of related species have been studied first-hand at MEL and NSW. Descriptive characters provided by Briggs & Crisp (1994) were assessed for sake of direct comparison, with additional characters added based on the descriptive formats of Renner *et al*. (2022) and Barrett *et al*. (2024).

Results and discussion

The New England plants differ from *Pultenaea parrisiae* and *P. paleacea* based on multiple morphological characters described in Table 1. In the key presented in Weston *et al*. (2024), specimens collected in the Carrai region key out as *P. parrisiae*, albeit with smaller flowers, and a revised key is also presented below.

Table 1. Comparison of selected morphological attributes that differentiate *Pultenaea rubescens* from *P. elusa*, *P. paleacea* and *P. parrisiae*.

Attribute	*P. elusa*	*P. paleacea**	*P. parrisiae*	*P. rubescens*
Stem indumentum	dense (glabrescent)	moderate to dense (glabrescent)	moderate (glabrescent)	sparse (eventually glabrescent)
Stipule length	5–9 mm long, c. 0.5 mm wide	3.8–5.2(–7.8) mm long, c. 1.2 mm wide	3–7 mm long, c. 0.5 mm wide	(4.8–)5.3–6.9 mm long, c. 0.7 mm wide
Juvenile leaves	unknown	unknown	3–10 mm long, 2–6 mm wide	8–21 mm long, 2–4 mm wide
Adult leaves	5–16 mm long, 0.6–2 mm wide	5.6–14 mm long, 0.8–1.8 mm wide	4–14(–17) mm long, 0.8–2.5(–3) mm wide	8–15(–24) mm long, 1.1–1.6(–2.4) mm wide
Petiole length	0.4–0.6 mm long	0.7–1.0 mm long	0.9–1.3 mm long	0.7–1.2 mm long
Leaf apex	strongly recurved	strongly recurved	strongly recurved	slightly recurved
Number of flowers in inflorescence	6–9	1–4(–5)	4–7	5–9
Flower bracts	6.2–7.7 mm long, 1.7–2.5 mm wide	7.1–8.3 mm long, c. 3 mm wide	4–5.5 mm long, 1.5–2 mm wide	3.1–5.7 mm long, 1.8–2.6 mm wide
Pedicels	0.4–0.7 mm long	0.9–1.1 mm long	1–1.5 mm long	0.5–1.1 mm long
Bracteole length	3–3.6 mm long	4–6 mm long	3–3.6 mm long	2.5–4.0 mm long
Bracteole position	attached 1.0–1.1 mm above base of calyx	attached c. 1.0 mm above base of calyx	attached at base of calyx	attached 0.2–0.7 mm above base of calyx
Calyx tube	2.2–3.0 mm long	2.9–3.3 mm long	2–2.7 mm long	1.4–1.9 mm long
Calyx lobes	1.3–1.8 mm long, acuminate	2.4–2.9 mm long, acuminate	1.5–3.3 mm long, acute to acuminate	1.4–2.6 mm long, acuminate
Standard	face yellow; 5.5–7 mm long, 3.6–3.8 mm wide	face yellow to orange; 8–12 mm long, 5.8–8.1 mm wide	face yellow; 5.0–6.0 mm long, 3.0–4.0 mm wide	face yellow-orange to red; 3.5–5.1 mm long, 2.4–4.8 mm wide
Wings	5.0–6.0 mm long, 1.0–1.3 mm wide	7.5–9.2 mm long, c. 2.5 mm wide	4.0–5.0 mm long, c. 1 mm wide	3.1–3.9 mm long, c. 0.9 mm wide

*Note: We here restrict the concept of *P. paleacea* to populations from the Sydney Basin north to Bulahdelah, in New South Wales (Figure 1). The treatment by de Kok and West (2004) partly confused *P. paleacea* with *P. rosmarinifolia* Lindl.

Figure 2. Field photographs of *Pultenaea rubescens* near Carrai. A, B. Habit in thick vegetation. C. Young plant after fire. D. leaves and old, terminal inflorescence. E. Old, terminal inflorescence with prominent bracteoles. F. Stipule on branchlet. G. Flowering branchlet. H, I. Inflorescence. Photos by P. Rossington, all previously posted on iNaturalist.

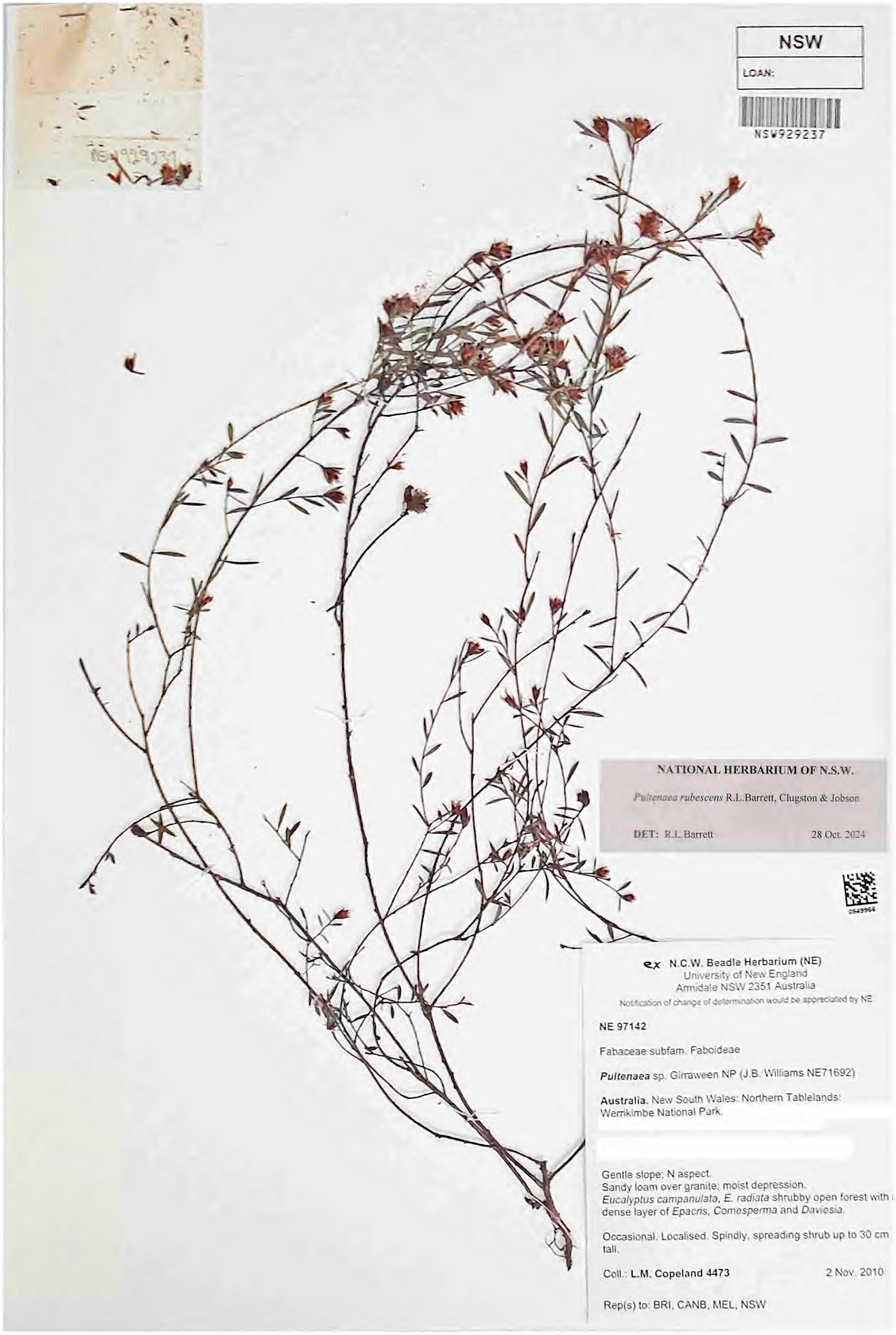

Figure 3. Herbarium specimen of *Pultenaea rubescens* (*L.M.Copeland 4473*; NSW 929237).

Modification to the New South Wales Flora Online key

The key in Weston *et al*. (2024) may be modified to accommodate the new species as follows:

12 Standard of flowers 8–12 mm long; bracteoles 4–6 mm long; small spreading shrub or subshrub ..... *Pultenaea paleacea*

12: Standard of flowers 3.5–7 mm long; bracteoles 3–4.0 mm long; diminutive, procumbent subshrub 12A

12A Stem indumentum dense; petioles 0.4–0.6 mm long; bracts on the flowers 6.2–7.7 mm long; wings of flowers 5.0–6.0 mm long..... *Pultenaea elusa*

12A: Stem indumentum sparse to moderate; petioles 0.7–1.3 mm long; bracts on the flowers 3.1–5.7 mm long; wings of flowers 3.1–5.0 mm long 12B

12B Juvenile leaves 3–10 mm long; leaf apex strongly recurved; bracts subtending flowers 1.5–2 mm wide; bracteoles attached at base of calyx; calyx tube 2–2.7 mm long; standard 5–6 mm long, face yellow; wings 4–5 mm long..... *Pultenaea parrisiae*

12B: Juvenile leaves 8–21 mm long; leaf apex moderately recurved; bracts subtending flowers 1.8–2.6 mm wide; bracteoles attached 0.2–0.7 mm above base of calyx; calyx tube 1.4–1.9 mm long; standard 3.5–5.1 mm long, face yellow-orange to red; wings 3.1–3.9 mm long ..... *Pultenaea rubescens*

Taxonomy

Pultenaea rubescens R.L.Barrett, Clugston & Jobson, *sp. nov.*

Type: NEW SOUTH WALES: North Coast: [precise locality withheld for conservation reasons] near Carrai, 11 Oct. 2022, *P.Rossington s.n.* (holo: NSW: 1224132; iso: CANB 956173).

Pultenaea sp. Girraween NP (J.B. Williams NE71692), *p.p.*, as to *Copeland 4473*.

Diminutive, procumbent *subshrub* with few, slender, trailing (or sometimes ascending over vegetation), few-branched stems 25–75(–90) cm long arising from a slender rootstock (nodulation common on fine roots). *Cotyledons* not seen. *Branchlets* spreading to ascending, 15–30 cm high; initially with a sparsely appressed silky hairs 0.6–1.6 mm long, but glabrescent on older stems; very shortly-ribbed below petioles (sometimes with a low ridge extending along the stem for up to 15 mm on dried specimens). *Stipules* lanceolate, tightly appressed to stem, fused for c. 9/10 their length (commonly tearing as they age, so appearing fused for only 1/2 their length), (4.8–)5.3–6.9 mm long, each c. 0.3 mm wide at sinus, weakly keeled, apex usually not spreading, acuminate, scarious, dark to pale brown at base, grading to translucent (except for midrib) towards apex, margins glabrous. *Seedling leaves* narrowly elliptic, 8–21 mm long, 2–4 mm wide, increasing in length as plants develop, larger than the adult form. *Adult leaves* alternate, sparse; petiole 0.7–1.2 mm long; lamina linear to narrowly oblanceolate, 8–15(–24) mm long, 1.1–1.6(–2.4) mm wide, discolorous, darker above; apex usually partly recurved, acuminate, apiculus 0.2–1.1(–1.4) mm long, dark brown to black; margins recurved, sometimes strongly so, but not hiding abaxial surface; adaxial surface distinctly concave to almost canaliculate, often with a row of simple appressed hairs along inconspicuous midrib; abaxial surface silky with persistent appressed hairs. *Inflorescence* a small, dense, terminal head of 5–9 solitary flowers; heads and individual flowers subtended by persistent, imbricate, pale-brown, scarious, enlarged stipules; stipules completely hiding pedicels, ovate to elliptic, 3.1–5.7 mm long, [fused pair] 1.8–2.6 mm wide at widest point, glabrous on face with uniformly ciliate margins, weakly keeled; reduced leaf-like bract acuminate or ±filiform, glabrous or villous, free portion 1.0–1.5(–2.1) mm long, reaching as long or longer than stipule apices. *Pedicels* 0.5–1.1 mm long, moderately hairy; floral bracteoles inserted 0.2–0.7 mm above base of calyx, 2.5–4.0 mm long, reaching 3/4–9/10 as long as calyx, lanceolate, acuminate, concave, keeled, with scattered long white hairs, particularly along outer edge of keel; floral stipules absent. *Flowers* 4.1–4.7 mm long; *calyx* tube broadly obconic, 1.4–1.9 mm long, greenish to red, moderately silky, appressed hairy; lobes 5, subequal, the upper pair shortly fused, triangular, 1.4–2.6 mm long, acuminate, greenish to reddish tinge on inside base of lobes, moderately densely silky hairy; *standard petal* hooded over keels and wings, ± circular when flattened, emarginate, 3.5–5.1 mm long including 1.3–2.0 mm claw, 2.4–4.8 mm wide, face orange-yellow to dark orange with faint to prominent reddish-orange ring near base with radiating lines reaching almost to the apex, reverse reddish orange; *wing petals* narrow-oblong, apex obtuse, 3.1–3.9 mm long including 1.8 mm claw, 0.9 mm wide, yellow with reddish-orange line along lower edge and apex; *keel petals* naviculate, ± narrow-oblong, 3.1–3.7 mm long including 1.25 mm claw, 0.8 mm wide (folded), ± equal to wings, dark red to almost purple near apex (and drying purple), grading abruptly to white at base; style and stamens reaching similar length, slightly upwardly curved near apex; *staminal filaments* 3.1–3.8 mm long; *anthers* c. 0.2 mm long, purple; *ovary* with a short stipe, 2-ovulate, 1.1–1.3 mm long, covered with densely silky with long white hairs to 0.5 mm long; *style* 2.9–3.1 mm long, slowly tapering, hairy in lower 1/3, slightly upwardly curved near apex; *stigma* inconspicuous, slightly capitate. *Fruit* ovoid, compressed, 3.8–4.3 mm long (excluding beak), 2.2–2.6 mm wide, c. 1.1 mm thick, with obtuse base, densely appressed sericeous; style partially persistent. *Seeds* released by opening of apical half of pod, dark brown, 1.6–1.8 mm long, 1.2–1.3 mm wide, aril white, c. 0.9 mm long, coralline, with long, irregular fingers. (Figures 2, 3).

Diagnostic characters: With affinities to *Pultenaea parrisiae* and *P. elusa,* differing in the sparser indument on the stems, larger juvenile leaves, distinctly petiolate adult leaves that are only moderately recurved at the apex, inflorescence bracts which are commonly shorter and broader, pedicels of intermediate length, bracteoles attached on calyx wall (as for *P. elusa*), and smaller calyx and corolla, as detailed in Table 1.

Distribution and habitat: *Pultenaea rubescens* occurs on the eastern fall of the New England Tableland near Carrai and Werrikimbe, south-east of Armidale, in the Northern Tablelands and North Coast Districts (Figure 1). The species grows in drainage depressions and the margins of usually perpetually wet sedge-dominated swamps surrounded by dry, sclerophyll eucalypt forest with a sparse canopy, occupying the interzone between these two habitats, only where this interzone is relatively extensive, and the shrub layer is not too tall or dense. It grows in wet heath with a ground layer of grasses, sedges and forbs, in sand over granite, at 900–1030 m altitude at three locations, two within 1 km of each other, and a third c. 47 km to the south. Other associated species recorded include *Asperula gunnii*, *Baloskion fimbriatum*, *Banksia marginata*, *Callistemon pallidus*, *C. pityoides*, *Comesperma* sp., Cyperaceae, *Daviesia*

sp., *Empodisma minus*, *Epacris brevifolia*, *E. paludosa*, *Eucalyptus campanulata*, *E. radiata*, *Gahnia* sp., *Gleichenia dicarpa*, *Gonocarpus micranthus*, *Hibbertia* spp., *Hypericum japonicum*, *Lepidosperma* sp., *Leptospermum* sp., *Pultenaea dentata*, *P. retusa*, Poaceae, *Prostanthera scutellarioides*, Restionaceae and *Sphaerolobium minus*.

Specimens examined: New South Wales [precise localities withheld for conservation reasons]: Northern Tablelands: Werrikimbe National Park, c. 60 km SE of Walcha, 2 November 2010, *L.M.Copeland 4473* (BRI, CANB 814010, MEL 2383816, NE 97142, NSW 929237); Werrikimbe National Park, 23 Nov. 2023, *T.Schmidt* (CANB, NSW); North Coast: Carrai, 21 Jan. 2022, *P.Rossington s.n.* (NSW 1119234); Carrai, 13 Oct. 2022, *P.Rossington s.n.* (CANB 956174, NSW); Carrai Plateau, 31 Oct. 2023, *P.Rossington s.n.* (NSW); Carrai Plateau, 1 Nov. 2023, *P.Rossington s.n.* (NSW); Carrai Plateau, 2 Nov. 2023, *P.Rossington s.n.* (NSW 1138182).

iNaturalist observations: 131191519, 156725273, 156725968, 159565254, 159567696.

Phenology: Flowering recorded for October–November, but probably starting in September; fruiting recorded for late November.

Etymology: From the Latin *rubescens* (becoming red), in reference to the face of the standard which can initially be yellow-orange, but quickly becomes red as the flowers mature.

Common name: Carrai Bush-pea.

Conservation Status: *Pultenaea rubescens* is currently known from 13 populations, in two localised areas less than 50 km apart. Four of these locations are primarily on private land (one extending into a conservation area). Surveys to date on the Carrai Plateau located about 283 plants at 56 observation points around 12 discrete sites over a distance of about 12 km. About 75% of individual plants located were found within existing conservation reserves. Individual populations range in size from a few plants to >50 individuals. These surveys are estimated to have examined 15–20% of the potential habitat in this area, suggesting there may be 1000–1200 plants on the Carrai plateau if habitat assessments and observed population densities are accurate estimates. These population estimates may be low due to difficulty in detection of these inconspicuous plants, and surveys being undertaken after peak flowering. No population estimates are available for the single known location in Werrikimbe National Park.

Some plants within these populations were observed to be senescing, despite good rainfall in the preceding three years. The species is thought to be relatively short-lived, with highest density post-fire, which stimulates seed germination. Specific threats have been identified in the form of grazing and trampling of swamp vegetation by escaped cattle in areas adjacent to private property with damaged fences and extensive damage to swamp vegetation by feral pigs in localised areas, which was most prominent in areas also affected by cattle grazing and historical soil disturbance. Likely Area of Extent: 1000 km^2. Known Area of Occupancy <5 km^2. As all known populations are highly restricted in extent, in very specific habitats, and population numbers are low, with ongoing threats to population size, the species warrants listing as Endangered (IUCN 2012: EN B1a,b(iii), B2a,b(iii)).

Notes: *Pultenaea* sp. Girraween NP (J.B. Williams NE71692) is superficially similar to *P. rubescens*, but differs most obviously in the prominent, broad stipules below the inflorescence. At NSW, two Copeland collections were initially ascribed to *P.* sp. Girraween NP, one of which (*L.M.Copeland 4473*) is here placed in *P. rubescens*.

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References

Barrett RL, Clugston JAR, Albrecht DE, Elkan L, Hosking JR, McCune SF, Jobson PC, Orme AE, Palsson RL, Renner MAM, Wardrop C, Weston PH (2024a) Revision of the *Pultenaea setulosa* species complex (Fabaceae: Mirbelieae) including fourteen new species. *Australian Systematic Botany* 37(SB23014): 1–105. DOI

Barrett RL, Clugston JAR, Cook LG, Crisp MD, Jobson PC, Lepschi BJ, Renner MAM, Weston PH (2021) Understanding diversity and systematics in Australian Fabaceae tribe Mirbelieae. *Diversity* 13(8): 391. DOI

Barrett, RL, Clugston, JAR, Orthia, LA, Cook, LG, Crisp, MD, Lepschi, BJ, Macfarlane, TD, Weston, PH, Wilkins, CF (2024b) East rarely meets West: a revised delimitation for *Pultenaea* (Fabaceae: Mirbelieae) with reinstatement of *Euchilus* and three new genera from south-west Western Australia. *Australian Systematic Botany* 37(SB23029): 1–31. DOI

Briggs JD, Crisp MD (1994) *Pultenaea parrisiae* (Fabaceae: Mirbelieae), a new species from south-eastern Australia. *Telopea* 5: 647–655. DOI

de Kok, RPJ, West JG (2002). A revision of *Pultenaea* (Fabaceae). 1. Species with ovaries glabrous and/or with tufted hairs. *Australian Systematic Botany* 15(1): 81–113. DOI

de Kok, RPJ, West JG (2003) A revision of the genus *Pultenaea* (Fabaceae) 2. Eastern Australian species with velutinous ovaries and incurved leaves. *Australian Systematic Botany* 16(2): 229–273. DOI

de Kok, RPJ, West JG (2004) A revision of the genus *Pultenaea* (Fabaceae). 3. The eastern species with recurved leaves. *Australian Systematic Botany* 17(3): 273–326. DOI

Department of Agriculture, Water and the Environment (2021) *Australia's bioregions (IBRA)*, IBRA7, Commonwealth of Australia. URL

IUCN (2012) *IUCN Red List Categories and Criteria. Version 3.1*. Second edn. (IUCN: Gland, Switzerland and Cambridge, UK) URL

Orthia LA, Crisp MD, Cook LG, de Kok RPJ (2005) Bush peas: a rapid radiation with no support for monophyly of *Pultenaea* (Fabaceae: Mirbelieae). *Australian Systematic Botany* 18(2): 133–147. DOI

Renner MAM, Barrett RL, Clarke S, Clugston JAR, Wilson TC, Weston PH (2022) Morphological and molecular evidence refute a broad circumscription for *Pultenaea glabra* (Fabaceae: Mirbelieae). *Australian Systematic Botany* 35(3): 225–277. DOI

Telford, I.R.H., Clugston, J.A.R. & Barrett, R.L. (2022) *Pultenaea williamsii* (Fabaceae: Mirbelieae), a new species endemic to the New England Tableland Bioregion of New South Wales. *Telopea* 25: 165–171. DOI

Weston PH, de Kok RPJ (2002) *Pultenaea,* Pp. 549–565 in Harden, GJ (ed.) *Flora of New South Wales* Vol. 2, revised edn (University of New South Wales Press: Kensington)

Weston PH, de Kok RPJ, Barrett RL, Renner, MAM (2024) *Pultenaea*. New South Wales Flora Online. URL (accessed 4 July 2024)